DOCUMENT RESUME

ED 402 204 SE 059 566

AUTHOR	Wilson, Karla G.
TITLE	Ozone: Does It Affect Me?
INSTITUTION	University City School District, St. Louis, MO.; Washington Univ., St. Louis, Mo.
SPONS AGENCY	National Inst. of Environmental Health Sciences (NIH), Washington, DC.
PUB DATE	96
CONTRACT	NIEHS-R25-ESO-6940
NOTE	180p.
PUB TYPE	Guides - Classroom Use - Teaching Guides (For Teacher) (052)
EDRS PRICE	MF01/PC08 Plus Postage.
DESCRIPTORS	Air Pollution; Chemical Reactions; Chemistry; *Conservation (Environment); Cooperative Learning; Environmental Education; Evaluation; Science Activities; *Science Experiments; Science Process Skills; Scientific Concepts; *Scientific Methodology; Secondary Education; Units of Study
IDENTIFIERS	Environmental Awareness; Learning Cycle Teaching Method; *Ozone; *Ozone Depletion

ABSTRACT

This curriculum unit on the ozone is intended for high school students and contains sections on environmental science and chemistry. It has been structured according to a learning cycle model and contains numerous activities, some of which are in a cooperative learning format. Skills emphasized include laboratory procedures, experimental design, data analysis, accessing information, critical thinking, systems modeling, and communicating results. The environmental science unit contains the following topics: location of ozone in the atmosphere; sources of ozone; effects of ozone pollution; and helping to reduce ozone pollution. The chemistry unit includes the following topics: chemical reactions that lead to ozone pollution and smog; identifying solutes and solvents in a homogeneous mixture; measurements of concentrations of very dilute solutions; absorption of ultraviolet light by stratospheric ozone; chemical reactions that lead to ozone depletion; and ways that reaction rates are influenced. The units also contain multiple choice tests, attitude surveys, and essay questions. (JRH)

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Ozone

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Ozone: Does It Affect Me? was created through the collaborative efforts of Washington University and University City High School. It is supported, in part, by funds from the National Institute of Environmental Health Sciences (NIEHS), grant # R25 ESO 6940.

The activities described in this curriculum unit are intended for high school students under direct supervision of adults. The sponsoring agencies cannot be responsible for any accidents or injuries that may result from the conduct of the activities without proper supervision, from not specifically following directions, or from ignoring cautions contained in the text.

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Ozone

Does It Affect Me?

ENVIRONMENTAL SCIENCE UNIT

Science Skills

The following science skills have been identified as central to student success in science learning:

Laboratory Procedures: Instrumental techniques, analytical methods.

Experimental Design: Scientific method, decision-making, sampling, controls.

Data Analysis: Making comparisons/ connections, statistical analysis, evaluating the impact of results on society.

Accessing Information: Computer search, accessing current data over Internet.

Critical Thinking: Problem solving, reasoning, synthesis, evaluation

Systems Modeling: Simulations, designing physical models

Communicating Results: writing, speaking, creating presentations.

Learning Cycle

This unit has been structured according to a learning cycle model. The basic components of the learning cycle are as follows:

Engage: Create interest, generate curiosity, and identify students' preconceived notions.

Explore: Provide opportunity to observe and test ideas.

Explain: Present definitions and concepts.

Elaborate: Students apply ideas to a new situation.

Evaluate: Assess student knowledge and skills.

Cooperative Learning

Studies indicate that girls attain higher achievement when taught science in cooperative groups (Berliner, 1992). Some of the activities in this unit are designed in a cooperative learning format. This format includes the following components:

Positive Interdependence: Examples of techniques that promote positive interdependence are using one paper or one set of materials for the group, giving each member a separate job or role, giving all group members the same reward, or giving each person only part of the information .

Individual Accountability: Examples of techniques that promote individual accountability include quizzing or testing individually, random selection of a paper from the group for grading, random oral quizzing of group members, individual homework, or asking for individual signatures.

Criteria for Success: Clearly identify the criteria for success for the lesson and communicate it to students.

Interpersonal skills: Identify, explain, demonstrate, teach, practice, monitor, and/or evaluate one or more social skills. (See the "Investigating Ozone" activity for a list of interpersonal skills that could be addressed.)

Main Concepts Presented In this unit

A. Location

1. The layers of the atmosphere can be divided into troposphere, stratosphere and mesosphere.
2. Ozone affects people in two ways. "Ozone in a good place" is found in the stratosphere, and "ozone in a bad place" is found in the troposphere.

B. Sources

1. Ozone in the lower atmosphere (troposphere) is a man-made pollutant.
2. Nitrogen oxides and hydrocarbons react to form ozone.
3. Cars and electricity are the main sources of nitrogen oxide pollution.
4. Gasoline fumes, oil based paints, lawnmowers, printers, and dry cleaners are some sources of hydrocarbon emissions.

C. Effects

1. Ozone pollution can affect human health by damaging the respiratory system.
2. Ozone can damage man-made materials, especially rubber and nylon.

D. Making a difference

1. I might personally contribute to ozone pollution in the following ways:
2. I can reduce ozone pollution in the following ways:

Assessment Tools

Included with this unit are a multiple choice test, and attitude survey, and an essay questions. These assesment tools can be administered as pre- and post tests for the unit to help assess student learning.

Unit Outline According to the Learning Cycle , Science Concepts and Science Skills

Activity	Concept	Learning Cycle	Science Skills
A. Investigating Ozone	A, B, C, D	Engage	Critical Thinking
B. Layers of the Atmosphere	A1, A2	Explore, Elaborate, Explain	Data Analysis
C. Take-home ozone survey	D1, D2	Explore	Data analysis
D. How do you contribute to ozone pollution?	B1, B3, D1, D2	Explore	Data analysis, Problem Solving
E. Ozone Pollution Sources and Effects (text + questions)	B1, B2, B3, B4	Explain	Accessing Information
F. Concept maping	A, B, C, D	Elaborate	Critical Thinking
G. Examining the effects of ozone on materials	C2	Explore	Laboratory Procedures
H. Fraying Fabrics and Ripping Rubber	C2	Elaborate	Experimental Design
I. In the News / Computer Scavenger Hunt	A, B, C, D	Explain	Accessing Information
J. Computer Presentaion Slide Show	A, B, C, D	Elaborate	Communicating Results

Multiple Choice Questions

Name: ____________________

Date: ____________________

Period: ____________________

1. Which material do you expect ozone to do the most damage to?
a. rubber
b. nylon
c. paper
d. cardboard
e. copper
f. limestone

2. The most common health effect of ground-level ozone pollution is:
a. thyroid cancer
b. lung damage
c. heart damage
d. brain damage
e. skin cancer
f. suffocation

3. Ozone pollution occurs in:
a. the troposphere
b. the stratosphere
c. the mesosphere
d. the tropopause
e. the stratopause
f. the mesopause

4. Which of the following is **NOT** a source of ozone pollution in the lower atmosphere?
a. cars
b. electricity use
c. oil-based paints
d. lawnmowers
e. Freon
f. charcoal bar-b-cues

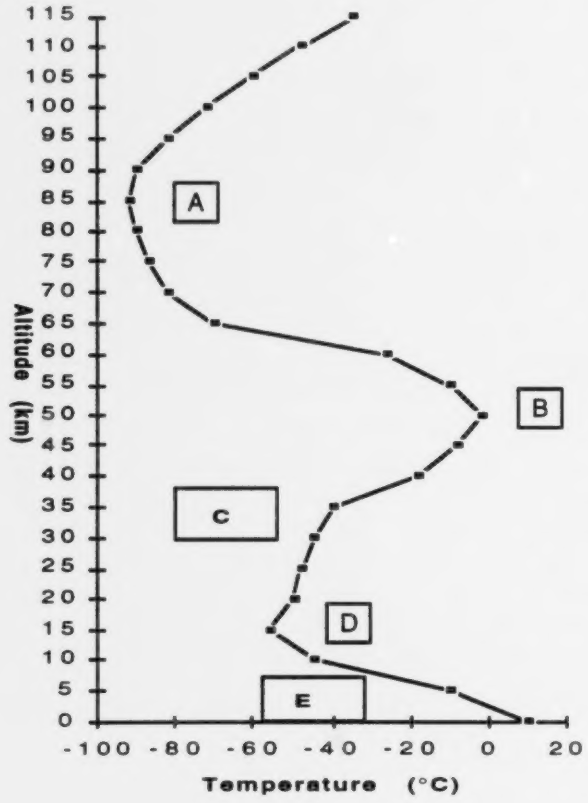
5. Which letter on the graph refers to the Tropopause? __________

6. Which letter refers on the graph refers to the Stratopause? ________

7. Which letter on the graph corresponds to the location of the stratospheric ozone layer?
______

8. Hydrocarbons and nitrogen oxides react in the troposphere to form ozone.
True **False**

9. Ozone in the stratosphere is a man-made pollutant.
True **False**



Multiple Choice Answers

Name: ____________________

Date: ____________________

Period: ____________________

1. Which material do you expect ozone to do the most damage to?

a. rubber
[✓ b.] nylon
c. paper
d. cardboard
e. copper
f. limestone

2. The most common health effect of ground-level ozone pollution is:

a. thyroid cancer
[✓ b.] lung damage
c. heart damage
d. brain damage
e. skin cancer
f. suffocation

3. Ozone pollution occurs in:

[✓ a.] the troposphere
b. the stratosphere
c. the mesosphere
d. the tropopause
e. the stratopause
f. the mesopause

4. Which of the following is **NOT** a source of ozone pollution in the lower atmosphere?

a. cars
b. electricity use
c. oil-based paints
d. lawnmowers
[✓ e.] Freon
f. charcoal bar-b-cues

5. Which letter on the graph refers to the Tropopause? D

6. Which letter refers on the graph refers to the Stratopause? B

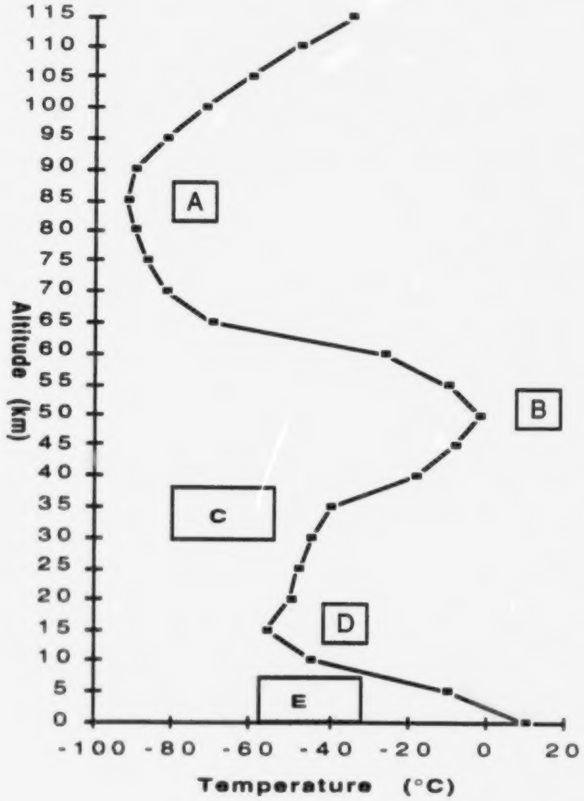
7. Which letter on the graph corresponds to the location of the stratospheric ozone layer? C

8. Hydrocarbons and nitrogen oxides react in the troposphere to form ozone.

[✓ True] False

9. Ozone in the stratosphere is a man-made pollutant.

True [✓ False]



8A

Essay Question

Name: ______________________

Date: ______________________

Period: ______________________

Discuss the sources and effects of ozone pollution.
How is ozone pollution different from ozone depletion?

Attitude Survey

Name: ______________________

Date: ______________________

Period: ______________________

---

1. I like studying about the environment.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

2. I can help my family better understand environmental issues.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

3. I don't contribute to air pollution.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

4. I am interested in studying about environmental issues.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

5. I talk about what we are learning in class with my family.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

6. I talk about what we are learning in class with my friends.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

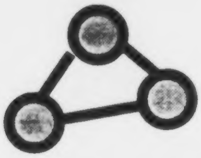
7. The information that I am learning in class will be useful to me in the future.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

8. I can think of ways to help solve air pollution problems.

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

Investigating Ozone



Name: ____________________

Date: ____________________

Period: ____________________

OBJECTIVES

- You will express preconceived notions regarding the subject of ozone.
- You will be invited to express your curiosity by recording questions you have about ozone.
- You will improve in your ability to carry out an assigned interpersonal skill.

MATERIALS

- Atom cards, laminated and cut apart; one per student
- One Investigating Ozone worksheet per team.
- Poster board or butcher paper
- Markers

Instructions:

1. After finding your teammates for this assignment, put your names in the spaces provided on the "Investigating Ozone" worksheet.

2. Take turns recording answers to the question "What do you know about ozone?" Student #1 writes down **one** answer, tells the team members what s/he has written, and then passes the sheet to student #2, who writes down a different answer, and so on.

3. When time is called, move on to the question, "What questions do you have about ozone?" using the same procedure. Team members can ask for help from other team members in generating ideas for questions, but they must take turns recording the questions on the worksheet.

4. Your team should generate at least five different responses to question #1 and at least 5 different responses to question #2.

5. Turn in the completed worksheet.

Investigating Ozone TEACHER BACKGROUND

OBJECTIVES

- Students will express preconceived notions regarding the subject of ozone.
- Students will be invited to express their curiosity by recording questions they have about ozone.
- Students will improve in their ability to carry out an assigned interpersonal skill.

MATERIALS

- Atom cards, laminated and cut apart; one per student
- One Investigating Ozone worksheet per team.
- Poster board or butcher paper
- Markers

SCIENCE SKILLS

- Critical Thinking

1. Select an interpersonal skill that you would like your students to work on improving. (See a list of interpersonal skills on the next page.) Tell your students that you want them to monitor how well their group performs the assigned skill, such as "Staying on task", during the course of the activity.

2. Assign students to groups of three, using the atom cards as follows:

   A. Explain that ozone is made of microscopic molecules. Each ozone molecule consists of three oxygen atoms attached to each other.
   B. Explain that each student represents an oxygen atom.
   C. Distribute one card per student.
   D. Tell the students they are to find the other atoms belonging to the molecule they represent, and form a team with those individuals. If your class cannot be evenly divided into groups of three, create one or two teams of oxygen molecules using two oxygen atom cards.

3. Distribute one worksheet per team. If you prefer to save on Xeroxing costs, you can have each student initial his/her own answer on a sheet of notebook paper.

4. At the end of the activity, ask each team to rate themselves on how well they feel they performed the assigned interpersonal skill. Collect the worksheets.

5. Follow up by summarizing questions and knowledge. Draw an ozone molecule on the board and discuss. As an extension of this activity, have each team place their questions on poster board or butcher paper on the walls. At the end of the unit, ask the students to select a question and answer it.

Some Interpersonal Skills

• move into groups quickly/quietly • talk in quiet voices • distribute materials	• sit face-to-face • use names and eye contact when speaking
• be sure everyone understands the task • share materials	• stay on task • carry out assigned task • monitor time
• paraphrase • active listening • joke to relieve tension	• ask for explanations • contribute ideas • challenge ideas
• ask questions • give evidence for conclusions • invite others to talk	• generate alternative answers • summarize ideas
• praise others • show respect for one another's ideas • criticize ideas, not people	• encourage participation • avoid put-downs • disagree in an agreeable way
• clarify disagreements within the group	• ask questions to help understand another's point of view

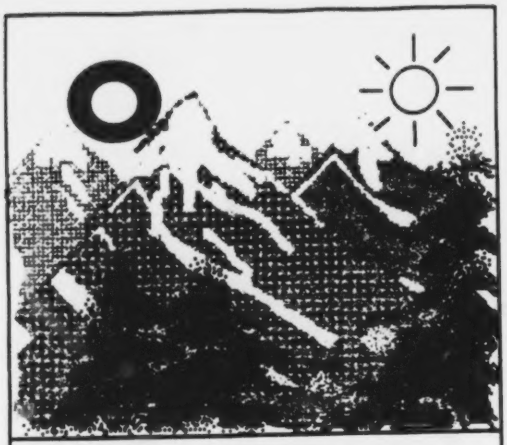
12A

Investigating Ozone

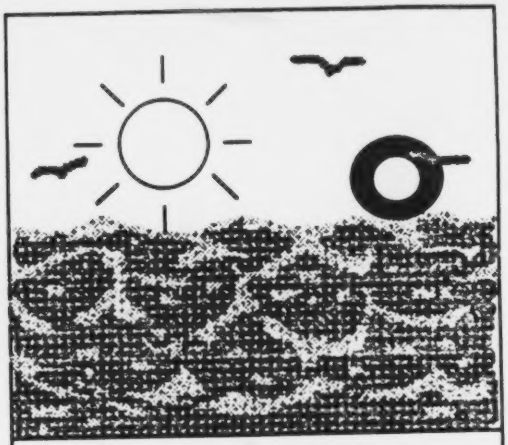
Names:	**Student #1** __________	**Student #2** __________	**Student #3** __________
#1 THINGS WE KNOW ABOUT OZONE :			
#2 QUESTIONS WE HAVE ABOUT OZONE:			

With 1 as a low score, and 10 a high score we rate our team as follows for carrying out the assigned interpersonal skill:

1 2 3 4 5 6 7 8 9 10



Ozone is made of three oxygen atoms. Find 2 other atoms within the same "environment" (the same background) as yours.



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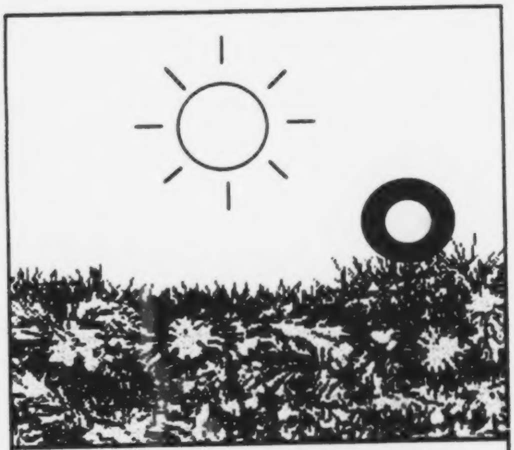

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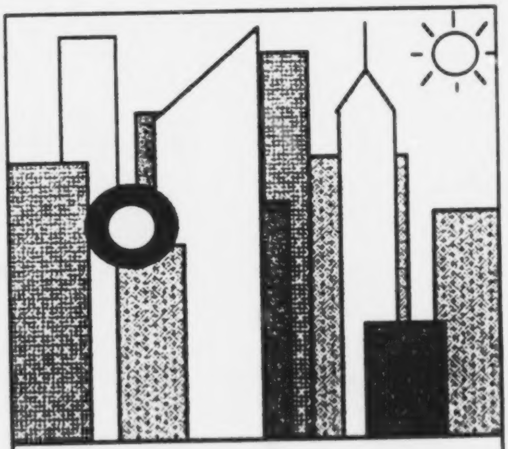
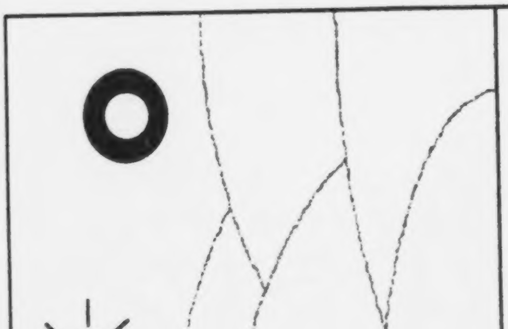


Ozone is made of three oxygen atoms. Find 2 other atoms within the same "environment" (the same background) as yours.

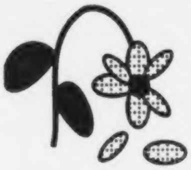


Ozone is made of three oxygen atoms. Find 2 other atoms within the same "environment" (the same background) as yours.

Oxygen molecules are made of two oxygen atoms. Find 1 other atom within the same "environment" (the same background) as yours.

Oxygen molecules are made of two oxygen atoms. Find 1 other atom within the same "environment" (the same background) as yours.

Air Pollution



A pollutant causes injury to plant, animal, or human life.

Air pollution is contamination of the air with unwanted or unhealthy molecules, especially with waste generated by human beings. This section provides a survey of air pollutants.

In the United Sates the term ambient air quality refers to outdoor air quality. National standards for clean air, called the National Ambient Air Quality Standards, provide the foundation for the formation of national and state laws and regulations that protect human health and the environment from exposure to ambient air.

Each state may have its own definition of air pollution. Most of the states' definitions include the following factors:

1. They are contaminants or combinations of contaminants.

2. They exist in a great enough quantity and/or for a long enough time that they may

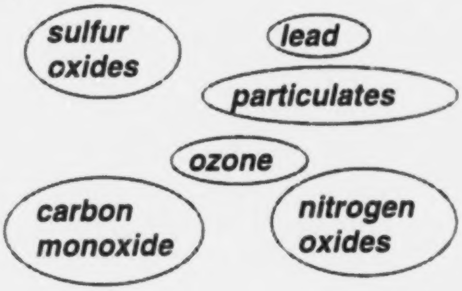
- Injure human, plant, or animal life
- damage property or
- Interfere with the enjoyment of life or property.

One way to define air pollution is to first define the makeup of "clean" or "normal" air. We can then describe air pollution as the presence of all other substances, or increases in those substances expected to be present, that result in damage to human beings, plants, animals, or materials.

Regulated Pollutants

Six pollutants (called criteria pollutants) have been regulated the longest (since 1970, in the United States). National health-based standards regulate these six pollutants by specifying their maximum allowable concentrations in the air we breathe.

1 sulfur oxides
2 nitrogen oxides
3 particulates
4 ozone
5 carbon monoxide
6 lead



Summary Sheet

Reference:
Air and Waste Management Association. 1991.
Environmental Resource Guide :
Air Quality. *Pittsburgh: Tennessee Valley Authority, Environmental Education Section.*

Pollutant	Description	Possible Effects
Sulfur Oxides (SOx)	gaseous compounds of sulfur and oxygen	• eye irritation • respiratory problems • lung damage • reacts in atmosphere to form acid rain • acid rain deteriorates buildings and statues • damages forests • kills aquatic life
Nitrogen Oxides (NOx)	gaseous compounds of nitrogen and oxygen	• lung damage • reacts in atmosphere to form acid rain • acid rain deteriorates buildings and statues • damages forests • kills aquatic life • reacts to form ozone and other pollutants (smog)
Particulates	very small particles of dust or other matter, including timy droplets of liquids	• eye irritation • lung damage • reduces visibility • discolors buildings and statues • damages crops
Ozone (O3)	gaseous pollutant formed from other air pollutants in the presence of sunlight	• lung damage • respiratory tract problems • eye irritation • damages vegetation • forms smog
Carbon Monoxide (CO)	colorless, odorless gas	• headaches, reduced mental alertness, death • heart damage
Lead (Pb)	metallic element made op of particulates	• brain and kidney damage • contaminated crops and livestock

Atmospheric Layers

Name: ______________________________

Date: ______________________________

Period: ______________________________

OBJECTIVES

- Graph the relationship between temperature and altitude.
- Identify layers of the atmosphere (troposphere, stratosphere, mesosphere) as a function of changes in temperature.
- Distinguish between the two separate locations in the atmosphere where ozone depletion and ozone pollution take place.

MATERIALS

- Data Table
- Question pages
- Spread Sheet program

Problem:

Why is the atmosphere divided into layers?

Procedure:

1. Construct a line graph from the data listed on the next page. Be sure to carefully plot the points, label the axis, and title the graph.
2. Answer the questions that follow.

Questions:

1. Carefully look at your graph. What happens to the temperature moving from 0 kilometers upward? Be specific.
2. If the troposphere is the layer of the atmosphere closest to the earth's surface, where might it end? __________ km.

   Why?

3. The upper limit or boundary of the troposphere is known as the **tropopause**. Write "tropopause" in the correct position on your graph.
4. Now determine the upper limit of the stratosphere. Where might it end? __________ km.

   Why?

5. This upper limit or boundary is known as the **stratopause.** Label this on your graph.
6. Finally, determine the upper limit or boundary of the mesosphere. Where might it end? _____ km.

   Why?

Altitude (kilometers)	Temperature (°C)	Altitude (kilometers)	Temperature (°C)
0	10	60	-26
5	-10	65	-70
10	-45	70	-82
15	-56	75	-87
20	-50	80	-90
25	-48	85	-92
30	-45	90	-90
35	-40	95	-82
40	-18	100	-72
45	-8	105	-60
50	-2	110	-48
55	-10	115	-35

HIGHLIGHT

The thinning of the ozone layer in the upper atmosphere results in increased ultraviolet radiation which can cause skin cancer, cataracts, and other damage to humans.

In the lower atmosphere, instead of protecting the planet, ozone harms the lungs, aggravates asthma, and damages crops

7. This upper limit is known as the **mesopause.** Label this on your graph.

8. You have now determined the location of the layers of the atmosphere.

9. The "ozone layer" prevents some ultraviolet radiation from reaching ground level. The ozone layer is at its highest concentration approximately 25-35 kilometers from the earth's surface. Man-made CFC's, which are used as refrigerants, propellants and solvents, deplete the ozone layer. Because the ozone layer protects the planet, we consider it to be "ozone in a good place". Which level of the atmosphere contains the ozone layer? ____________________

10. Label the ozone layer on your graph.

11. At the earth's surface, nitrogen oxides and hydrocarbons from cars, power plants and other industries react in the air to form ozone. Because ozone pollution near the earth's surface harms people and plants, we consider it to be "ozone in a bad place". Which layer of the atmosphere contains ozone pollution? ____________________

12. Place the label "ozone pollution" on the appropriate location of your graph.

13. After printing out the graph color the three layers of the atmosphere in three separate colors, and make a legend for reference.

14. Answer each of the following questions on a separate index card and place them in the shoebox marked "location" at the front of the room. Include your name on the index card. a) Where is ozone located in the atmosphere? b) How can ozone in one location be distinguished from the other?

Atmospheric Layers TEACHER BACKGROUND

OBJECTIVES

- Students will graph the relationship between temperature and altitude.
- Students will identify layers of the atmosphere (troposphere, stratosphere, mesosphere) as a function of changes in temperature.
- Students will distinguish that ozone depletion and ozone pollution take place in two separate locations in the atmosphere.

MATERIALS

- Data Table
- Graph
- Spreadsheet program

SCIENCE SKILLS

- Data Analysis

In this exercise, students can draw the graph by hand, or they can create the graph on a computer using a spreadsheet program, such as Microsoft Works, Claris Works, or Excel. Included in this unit are generic graphing instructions for Claris Works. Graphing guidelines for other spreadsheet programs will be similar.

Have the students enter both columns of points into a spreadsheet. When they would like to plot the points into a chart, make sure they use the first column of points as the "X-Values" in an X-Y chart.

The best type of chart to use for this plot is a simple line graph. This will allow the students to see the change in temperature from one layer to the next.

If you have the students switch the positions of their x and y axes, so that the altitude axis is vertical (see graphing instructions), the graph will create a better visual model for comparing with the actual atmosphere.

Now when students look at the graph, they should clearly be able to see the different layers associated with the atmosphere.

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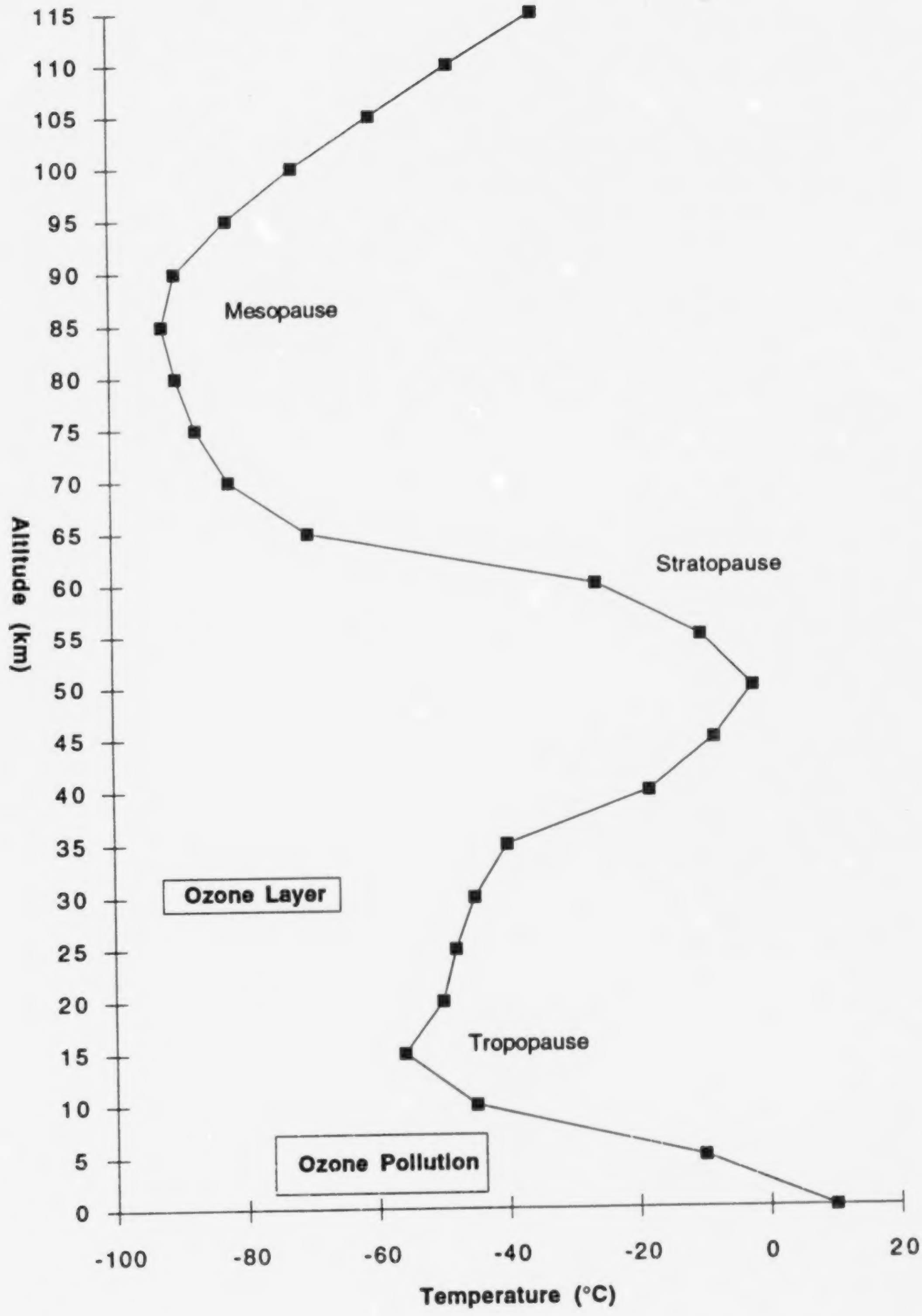


Atmospheric Layers Graph

Generic Graphing Instructions For Claris Works

- Start up **Claris Works** (click on the Claris Works icon)
- Choose **Spread Sheet**
- Copy your data table to the spreadsheet
- High light your data
- Under the **Options** menu choose **Make Chart**.

Do Not Click Okay until you have gone through every category!

- Click on **Gallery**
    - Click on the type of graph you would like
- Click on **Axis**
    - Label your Y axis according to the data found in column B
    - Click on X axis
    - Label your X axis according to the data found in column A
- Series
- Click on **Labels**
    - Type your title
    - Unclick the X next to legend to get rid of the legend.
- Click on **General**
    - Click on Columns
    - Click on First Column

Now click Okay

Save Your Graph!!!!!

- Under the File menu choose Save
- Type a name for your document
- Click **Save**

Use the following to customize your graph

Any of your original choices can be changed by following the steps above. For additional formatting refer to the instructions below.

Does your X axis need to be longer than your Y axis? If so...

Under the File menu choose Page Setup
Click on the picture of the sideways person

Double click on your graph to bring up the chart options screen.

To switch the positions of the X and Y axes
- Click on **Gallery**
- Click in the **box** to the left of the word Horizontal.

To change the ranges of your axes
- Click on **Axis**
- Click on the axis you would like to change
- Enter a minimum value
- Enter a maximum value
- Enter a step size. (This will determine how the axis labels are broken down. For example you could have a mark every 10 units or every 20 units)

To label your data
- Click on **Series**
- Click on the **box** to the left of Label Data

To change the placement of your legend or title
- Click on **Labels**
- If you want a horizontal legend
  - Click on the **box** next to the word Horizontal
  - Click on the diagram to the right to chang the placement of your title (top) or your legend (bottom)

Before printing

Under the **View** menu choose **Show Tools**

- Change all colors to pastels (except line graphs)
    - Click on the color box in the legend you want to change (A white circle will appear in the box.)
    - In the tools box (over to the left) click and hold on the upper most rainbow box
    - Drag to the Pastel color of your choice
    - **Repeat** for every series in your legend
- If you have labeled your data
    - Under the **Format** menu click and hold **Text Color**
    - Drag to **black**
- Correctly place your graph on the page
    - Get rid of cells and cell labels
        - Click on a cell in your spreadsheet
        - Under the **Options** menu choose **Display**
        - Click on all of the X's so that there aren't any left
        - Click **Okay**
    - Resize the graph
        - Under the **View** menu choose **Page View**
        - Click inside your graph and drag it so that the graphs upper left hand corner is in the same place as the page border's upper left hand corner
        - Click on the box at the lower right hand corner of your graph and drag it so it is in the same place as the page border's lower right hand corner
        - **Remember**- you can continue to move it around until you let go of the mouse button!
    - Add your name
        - In the tools box (over to the left) click on the A tool
        - Click on an appropriate place on your graph
        - Type your name
        - Click anywhere on your finished graph

Save your graph again!

Under the **File** menu choose **Print**
    Click **Print**

The Atmosphere

HIGHLIGHT

Ozone in the troposphere is increasing.

Ozone in the stratosphere is decreasing.

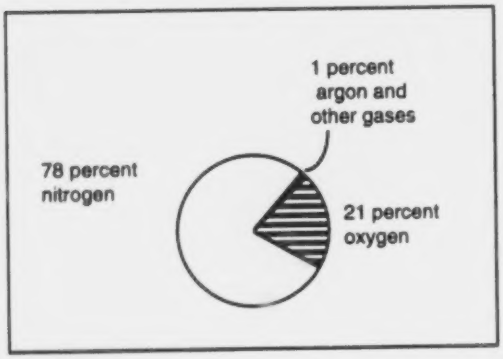
Air is everywhere. We can feel it move, we breathe it, and we live in it. We cannot live without it. What is air? Air consists of a mixture of different gases. We call the gases that surround the earth the **atmosphere.**

Composition of the Atmosphere

There are two major components of unpolluted air at ground level.

- Nitrogen makes up about 78 percent of the atmosphere.
- Oxygen makes up about 21 percent.

The remaining 1 percent consists primarily of argon, with smaller amounts of water, carbon dioxide, neon, helium, methane, krypton, hydrogen, nitrous oxide, and xenon, with ozone and other trace gases present in variable amounts. This mixture of gases is what we breathe every day.



This graph represents the percent composition of the Earth's atmosphere.

Generally, the nitrogen and oxygen that account for 99 percent of the atmosphere mix uniformly and evenly. On a global basis, however, there are differences in atmospheric composition. For example, the atmospheric composition in a desert region is different from that of a rain forest region. The water content of the atmosphere varies from 0-4% at different places or at different times. When thinking on a regional basis, however, the composition, or makeup, of gases at one point in the region is similar to the composition at any other point. The reason that the distribution of atmospheric gases does not vary significantly within the region is that air in the region is constantly circulating and mixing.

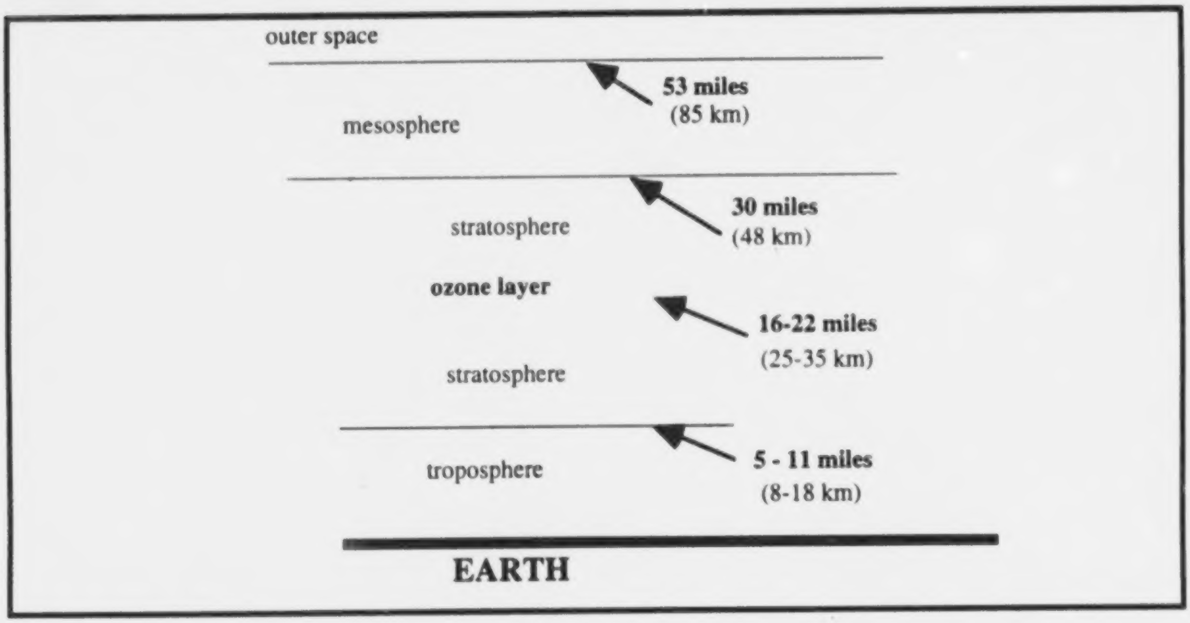
Layers Of The Atmosphere

The atmosphere is divided into layers. There are no distinct boundaries between layers. Each layer has its own specific characteristics and properties.

The Troposphere

The troposphere is the part of the atmosphere in which weather occurs.

Air gets thinner (less dense) as elevation increases. (This change explains why mountain climbers sometimes carry extra oxygen to help them breathe better when they are at high altitudes.) Most of the atmosphere is found near the surface of the earth. Ninety percent (90%) of the total weight of the atmosphere is located



The atmosphere is divided into layers. There are no distinct boundaries between layers.

within 10 miles of the earth's surface. This region is called the **troposphere**. The height of the troposphere is not constant. It ranges from a height of approximately 5 miles at the North and South poles to a height of 11 miles at the equator.

HIGHLIGHT

Ozone in the troposphere acts as a pollutant and contributes to lung damage. Ozone in the stratosphere protects us from ultraviolet radiation.

In the troposphere, the temperature decreases as elevation increases. This explains why there is snow on some mountains all through the summer months, even when people at the base of the mountain are wearing shorts and tee shirts.

The Stratosphere

The stratosphere lies above the troposphere. Unlike the troposphere, in the stratosphere, the temperature increases as altitude increases. The temperature in the stratosphere reaches a maximum at its upper edge. Within the stratosphere, there is a layer of ozone gas, called the ozone layer.

The Mesosphere

The mesosphere lies above the stratosphere and has a temperature/altitude relationship that is similar to the troposphere. At this altitude, there is a decreased level of ozone or other energy-absorbing gases, and the temperature decreases as the altitude increases. At the outer edges of the mesosphere and the areas beyond the mesosphere, molecules and atoms can escape the earth's atmosphere and become part of outer space.

Ozone Survey

Name: ____________________

Date: ____________________

Period: ____________________

OBJECTIVES

- Collect and analyze data related to the impact of individuals on ozone pollution.
- Communicate with parents about ozone unit studies.
- List ways that individual actions might affect ozone pollution in the lower atmosphere.

MATERIALS

- Three survey copies
- Tally sheets
- Optional computer access to create graphs.

Instructions:

1. Ask one parent, one teacher, and one student to each fill out a copy of the ozone survey.
2. Tally the survey responses for the questions assigned to your team, using the appropriate tally sheet.
3. Answer the questions appropriate to your team following the instructions on the appropriate worksheet.

Ozone Survey

PLACE AN X IN THE BOX THAT PROVIDES THE BEST ANSWER.

When I mow the lawn, I use the following type of lawnmower:
o gas-powered o electric o hand-powered o I never mow the lawn

The last time I painted something, the paint I used was:
o water-based o oil-based o I don't remember o I don't paint

When my family bar-b-cues we use:
o lighter fluid o "chimney" starter o gas grill o We don't bar-b-cue

I know someone who has asthma.
o Yes o No

CIRCLE THE NUMBER THAT CORRESPONDS WITH THE BEST ANSWER.

	Always	Usually	Sometimes	Rarely	Never
I exercise outdoors on summer afternoons.	1	2	3	4	5
I get respiratory illnesses.	1	2	3	4	5
I participate in a carpool.	1	2	3	4	5
I ride the bus or lightrail.	1	2	3	4	5
I ride a bicycle or I walk to work or to school.	1	2	3	4	5

ANSWER THE FOLLOWING ONLY IF YOU ARE OLD ENOUGH TO DRIVE.

	Always	Usually	Sometimes	Rarely	Never
I turn the car engine off if I am stopped for more than one minute.	1	2	3	4	5
I "top off" the gas tank when filling it.	1	2	3	4	5
I use the drive-thru lanes at fast food restaurants instead of going inside.	1	2	3	4	5
I change my oil every six months or less.	1	2	3	4	5
I get regular tune-ups for my car.	1	2	3	4	5
I check my tire pressure regularly.	1	2	3	4	5

Team A Tally Sheet

lawnmower	gasoline	electric	hand power	don't mow
paints	water-based	oil-based	don't remember	don't paint
bar-b-cue	lighter fluid	chimney	natural gas	don't bar-b-cue

Tally the surveys using the form provided. Upon completion of the appropriate stack of surveys, check off the numbers below:

_____ survey# 1-10

_____ survey# 11-20

_____ survey# 21-30

_____ survey# 31-40

_____ survey# 41-50

_____ survey# 51-60

_____ survey# 61-70

_____ survey# 71-80

_____ survey# 81-90

Team B Tally Sheet

	Yes	No
I know someone who has asthma.		

	Always 1	Usually 2	Sometimes 3	Rarely 4	Never 5
I exercise outdoors on warm summer afternoons.					
I get respiratory illnesses.					

Tally the surveys using the form provided. Upon completion of the appropriate stack of surveys, check off the numbers below:

_____ survey# 1-10

_____ survey# 11-20

_____ survey# 21-30

_____ survey# 31-40

_____ survey# 41-50

_____ survey# 51-60

_____ survey# 61-70

_____ survey# 71-80

_____ survey# 81-90

Team C Tally Sheet

	Always 1	Usually 2	Sometimes 3	Rarely 4	Never 5
I participate in a carpool.					
I ride the bus or lightrail.					
I ride a bicycle or I walk to school or to work.					

Tally the surveys using the form provided. Upon completion of the appropriate stack of surveys, check off the numbers below:

_____ survey# 1-10

_____ survey# 11-20

_____ survey# 21-30

_____ survey# 31-40

_____ survey# 41-50

_____ survey# 51-60

_____ survey# 61-70

_____ survey# 71-80

_____ survey# 81-90

Team D Tally Sheet

	Always 1	Usually 2	Sometimes 3	Rarely 4	Never 5
I turn the car engine off if I am stopped for more than one minute.					
I "top off" the gas tank when filling it.					
I use the drive-through lanes at fast food restaurants instead of going inside.					

Tally the surveys using the form provided. Upon completion of the appropriate stack of surveys, check off the numbers below:

_____ survey# 1-10

_____ survey# 11-20

_____ survey# 21-30

_____ survey# 31-40

_____ survey# 41-50

_____ survey# 51-60

_____ survey# 61-70

_____ survey# 71-80

_____ survey# 81-90

Team E Tally Sheet

	Always 1	Usually 2	Sometimes 3	Rarely 4	Never 5
I change my oil every six months or less.					
I get regular tune-ups for my car.					
I check my tire pressure regularly.					

Tally the surveys using the form provided. Upon completion of the appropriate stack of surveys, check off the numbers below:

_____ survey# 1-10

_____ survey# 11-20

_____ survey# 21-30

_____ survey# 31-40

_____ survey# 41-50

_____ survey# 51-60

_____ survey# 61-70

_____ survey# 71-80

_____ survey# 81-90

Ozone Survey Worksheet for Team A

If you were going to implement a publicity campaign to change peoples habits in relation to ozone pollution, which tool would you focus on and why?

1. Describe what each tool on the ozone survey has to do with ozone pollution.

2. Divide the tools into two categories-those that contribute more to ozone pollution ("dirty air" tools), and those that reduce the contribution to ozone pollution ("clean air" tools).

3. Calculate the percent of the population that uses each tool.

"Dirty Air" Tools	%	"Clean Air" Tools	%
1.		1.	
2.		2.	
3.		3.	
		4.	
		5.	

4. Which "dirty air" tool is used the most?

5. Answer the question at the top of this section: "If you were going to implement a publicity campaign to change peoples habits in relation to ozone pollution, which tool would you focus on and why?"

Ozone Survey Worksheet for Teams B, C, D, and E

How often do people carpool? Do they tend to carpool more or less often than they take mass transit? Which car maintenance or driving behaviors do people tend to do the most? To calculate the comparative frequency of occurrence of a set of habits, fill in the worksheet below.

1. What do the behaviors listed on your tally sheet have to do with ozone pollution? Explain.

2. Calculate the relative frequency of occurrence of the behaviors.

Step A Fill in the name of the habit.

Step B Calculate the percent responses for each answer.

Step C Multiply each percent by the number shown.

Step D Add the sum of the numbers in the far right column. The higher this final number is, the more frequent the occurrence of the behavior.

Habit #1____

Percent responding with “Always” ____________% x 5 = ______

Percent responding with “Usually” ____________% x 4 = ______

Percent responding with “Sometimes” ____________% x 3 = ______

Percent responding with “Rarely” ____________% x 2 = ______

Percent responding with “Never” ____________% x 1 = ______

Total =100% **Total =** ______

Habit #2____

Percent responding with "Always" ____________% x 5 = ______

Percent responding with "Usually" ____________% x 4 = ______

Percent responding with "Sometimes" ____________% x 3 = ______

Percent responding with "Rarely" ____________% x 2 = ______

Percent responding with "Never" ____________% x 1 = ______

Total =100% **Total =_____**

Habit #3____

Percent responding with "Always" ____________% x 5 = ______

Percent responding with "Usually" ____________% x 4 = ______

Percent responding with "Sometimes" ____________% x 3 = ______

Percent responding with "Rarely" ____________% x 2 = ______

Percent responding with "Never" ____________% x 1 = ______

Total =100% **Total =_____**

3. Answer the appropriate question below.

TEAM B. People who like to exercise outdoors and asthmatics are two segments of the population at a higher risk of being affected by ozone pollution. Based on your survey results, on which of these two target populations would you most want to focus a publicity campaign? Why?

TEAM C. Taking alternate forms of transportation can help reduce ozone pollution. If you were running a publicity campaign, which form of alternate transportation would need the most attention? Why?

TEAM D. Changing driving habits can help reduce ozone pollution. If you were running a publicity campaign, which driving habit would need the most attention to get drivers to change their ways? Why?

TEAM E. Car maintenance habits can help reduce ozone pollution. If you were running a publicity campaign, which car maintenance habit would need the most attention to get drivers to change their ways? Why?

Ozone Survey

TEACHER BACKGROUND

OBJECTIVES

- Students will collect and analyze data related to the impact of individuals on ozone pollution.
- Parents will increase their awareness of their personal impact on ozone pollution, and of the unit their son or daughter is studying.
- Students will list ways that their personal actions might affect ozone pollution in the lower atmosphere.

MATERIALS

- ozone survey sheets
- index cards
- computer spreadsheet program (optional)

SCIENCE SKILLS

- Data Analysis

Procedure

1. Have students fill out the ozone survey, then send home the letter and survey for parents to fill out.

2. When the surveys have been collected, number the surveys then divide the students into teams of two or three. Give each team one of the following problems to solve, and the corresponding tally sheet and worksheet.

   A. If you were going to implement a publicity campaign to change peoples habits, which tool would you focus on and why?

   B. People who like to exercise outdoors and asthmatics are two segments of the population at a higher risk of being affected by ozone pollution. Based on your survey results, on which of these two target populations would you most want to focus a publicity campaign? Why?

   C. Taking alternate forms of transportation can help reduce ozone pollution. If you were running a publicity campaign, which form of alternate transportation would need the most attention?

   D. Changing driving habits can help reduce ozone pollution. If you were running a publicity campaign, which driving habit would need the most attention to get drivers to change their ways?

   E. Car maintenance habits can help reduce ozone pollution. If you were running a publicity campaign, which car maintenance habit would need the most attention to get drivers to change their ways?

3. As a culminating exercise, have students fill out index cards with their ideas or ideas from the survey about sources of and solutions to ozone pollution, add their names to the cards, and place the cards in the "Sources" and "Solutions" shoe boxes.

BEST COPY AVAILABLE

4. As an optional extension of this exercise, have students create pie graphs by hand or with a computer to create a visual display of the relative frequency of each behavior. A further extension can be to have students create posters based on their analysis of the surveys, and post them around the school.

5. A sample letter to parents to send home with students along with the surveys given below.

Letter to Parents

Dear Parent or Guardian:

The enclosed survey is part of a unit on ozone that we will be studying in Environmental Science class this semester. The ozone unit will include an emphasis on laboratory work and using computers to analyze data and communicate results.

Please fill out the survey and return it to your son or daughter to bring back to school. There are no "right" answers. Just fill it out as accurately as possible. The students will be responsible for tallying and analyzing the results of the survey. Please do not put your name on the survey.

Thank you very much for your participation and assistance in helping to make this project a success.

Sincerely,

How Do You Contribute to Ozone Pollution?

Name: ____________________

Date: ____________________

Period: ____________________

OBJECTIVES

- Analyze data related to your personal contribution to air pollution from electricity consumption
- Use critical thinking skills to create a plan for reducing the contribution of automobiles to ozone pollution.

MATERIALS

- handouts
- your home
- calculator

Instructions:

Electricity

1. Conduct a survey of your home. Going room by room, make a list of all the items that use electricity.

2. Record the wattage of each appliance. The wattage refers to the amount of power that the appliance uses. The wattage is usually listed somewhere on the back of, or underneath, the appliance. If the wattage is not listed, the voltage and amperes should be. To calculate wattage, multiply the voltage by the amperes:

   volts x amps = watts

   Or, refer to the graph with the title "Wattage of Common Household Appliances".

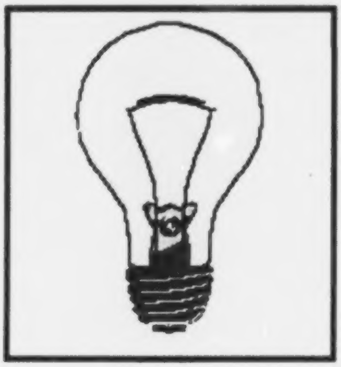
   You will need to look at each light bulb in your house to determine the wattage. Most light bulbs are 40-100 watts. Add up the total watts used for lighting in each room.

3. Record how much time each electric appliance or light bulb is used during a 24 hour period.

4. Calculate the watt-hours for each electric appliance or light bulb by multiplying the number of watts times the number of hours used.

5. Add up the total number of watt-hours per day for all the electric appliances in your home.

6. A kilowatt-hour equals 1000 watt-hours. How many kilowatt-hours are used in your home per day? ____________

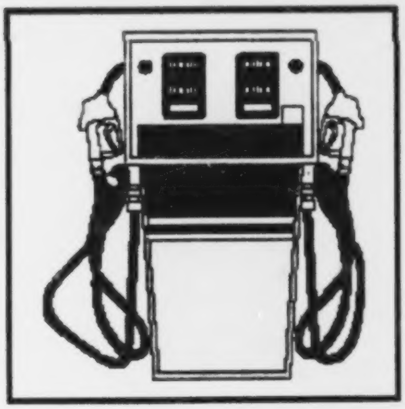


Electricity from coal fired power plants results in the release of nitrogen oxides into the atmosphere. Nitrogen oxides react to form ozone.

7. Every 100 kilowatt-hours of electricity used causes the release of about a kilogram of nitrogen oxides from coal-fired power plants into the atmosphere. Nitrogen oxides react in the air to produce ozone. Assuming your electricity comes from a coal-fired power plant, how much nitrogen oxide pollution does your home contribute from electricity use in one day? How much does your home contribute in one year? (If the fuel source for the power plant that provides your electricity is nuclear, wind power or hydropower, your actual contribution to nitrogen oxide pollution will be less than this amount.)

8. Propose a cut-back in electric usage to reduce the amount your family contributes to ozone pollution. Where would you reduce the use of electricity and why? Show the amount of decrease. Calculate the percent decrease.

$$\% \text{ decrease} = \frac{\text{original amount - the new reduced amount}}{\text{original amount}}$$

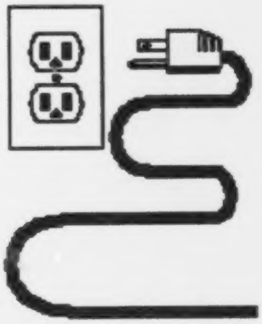


Spilled gasoline, vapor fumes, and high engine temperatures contribute to ozone pollution.

Transportation

A second major contributor to air pollution is the automobile. Cars release both nitrogen oxides and hydrocarbons, which react in the atmosphere to form ozone.

1. The federal government currently taxes gasoline at the rate of 18.4¢ per gallon. In addition, the state of Missouri levies a 13¢ tax for each gallon of gas. One proposal for reducing air pollution is to increase the gasoline tax, which would increase the price of gasoline. Presumably, people would drive less as the price of gasoline increases, thus reducing the contribution of cars to ozone pollution. Do you agree or disagree with this proposal? Why or why not?
2. In Mexico City, each car is issued a colored sticker. A car can only be driven on certain days of the week, depending on the color of the sticker. Do you think it would be a good idea to implement this plan in the United States? Why or why not?
3. Suggest your own proposal for reducing the contribution of automobiles to ozone pollution.



Electric power production releases nitrogen oxides into the atmosphere. The nitrogen oxides react in the presence of sunlight to form ozone.

Summary

After completing this activity, answer the following questions on separate index cards and place them in the shoeboxes marked "Sources" and "Solutions" at the front of the room. Include your name on the cards. a) Discuss and describe some sources of ozone pollution. b) How can ozone pollution be reduced?

Estimated Watt-Hours per Day of Selected Household Appliances[1]	
Clock	50
Freezer-Frostless (15 cu. ft. chest type)	4000
Freezer-Frostless (15 cu. ft. chest type*)	2500
Freezer-Frostless (15 cu. ft. upright)	5000
Freezer-Frostless (15 cu. ft. upright*)	3000
Freezer-Frostless (15 cu. ft. manual defrost)	3000
Refrigerator-Frostless (16 cu. ft.)	5000
Refrigerator-Frostless (16 cu. ft.*)	2500
Refrigerator-Frostless (23 cu. ft. side-by-side)	10,000
Refrigerator-Frostless (23 cu. ft. side-by-side*)	4000
Refrigerator-Frostless (10 cu. ft. manual defrost)	2000
Toothbrush with charger	30
Water Heater-electric	13,000
Waterbed Heater	4000
Well pump	3000

* Post-1980 Energy-Efficient Models

Estimated Watt-hours per use of Selected Household Appliances[1]		# of times used per day	# of watt-hours per day
Garbage Disposal	10		
Curling Iron	10		
Toaster	50		
Corn Popper	100		
Ice Cream Freezer	100		
Hair Curlers	100		
Coffee maker	200		
Hair Dryer	250		
Washing machine, cold water	250		
Waffle Iron	330		
Deep Fryer	1000		
Clothes Dryer, electric	3000		
Dishwasher (includes 3000 watts to heat water)	4000		
Self-cleaning feature on electric oven	6000		
Washing machine + electricity for hot water	6250		

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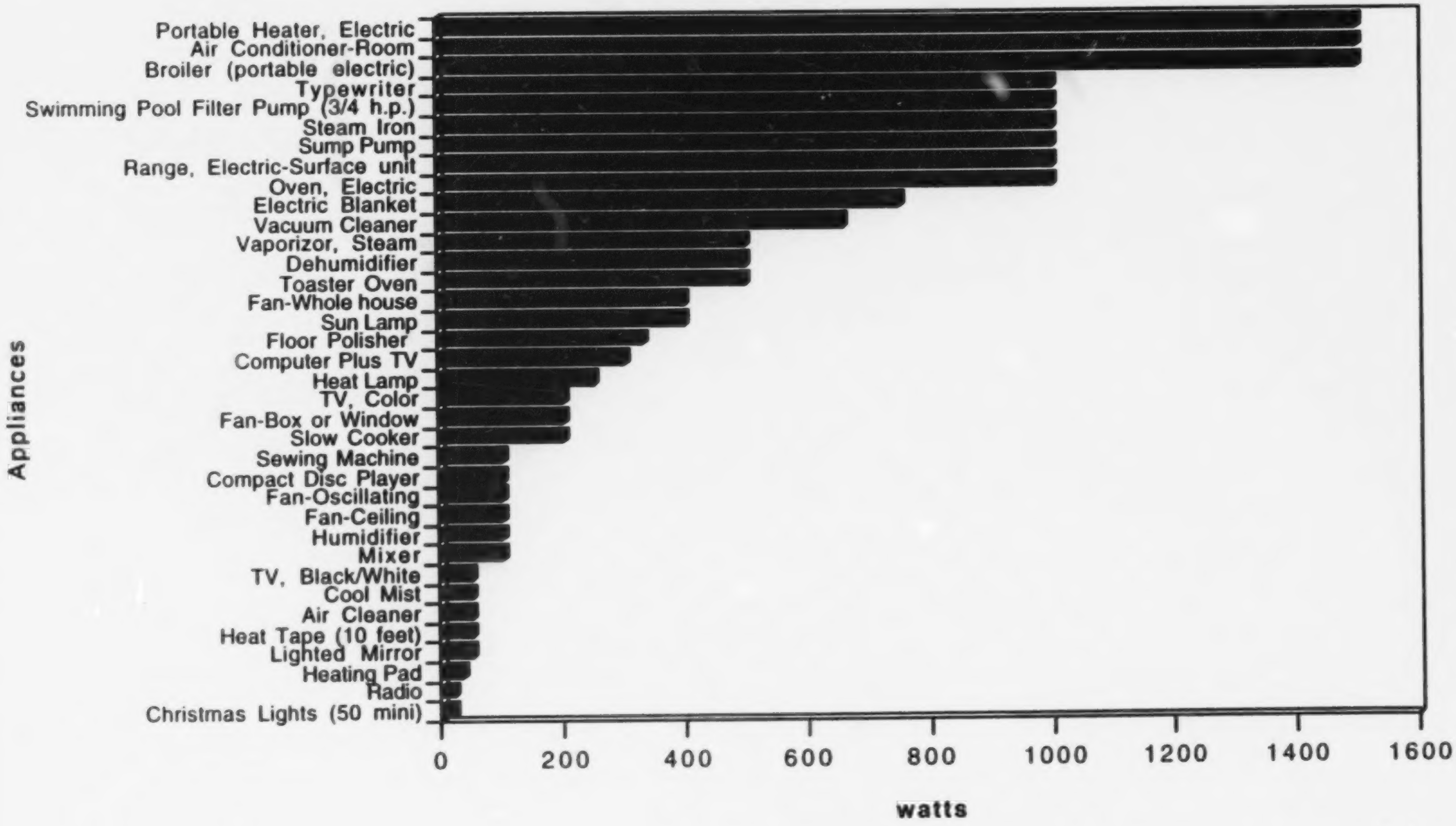
[1] Figures from "Appliance and Equipment Cost of Operation"; CU Energy Management, City Utilities of Springfield, MO

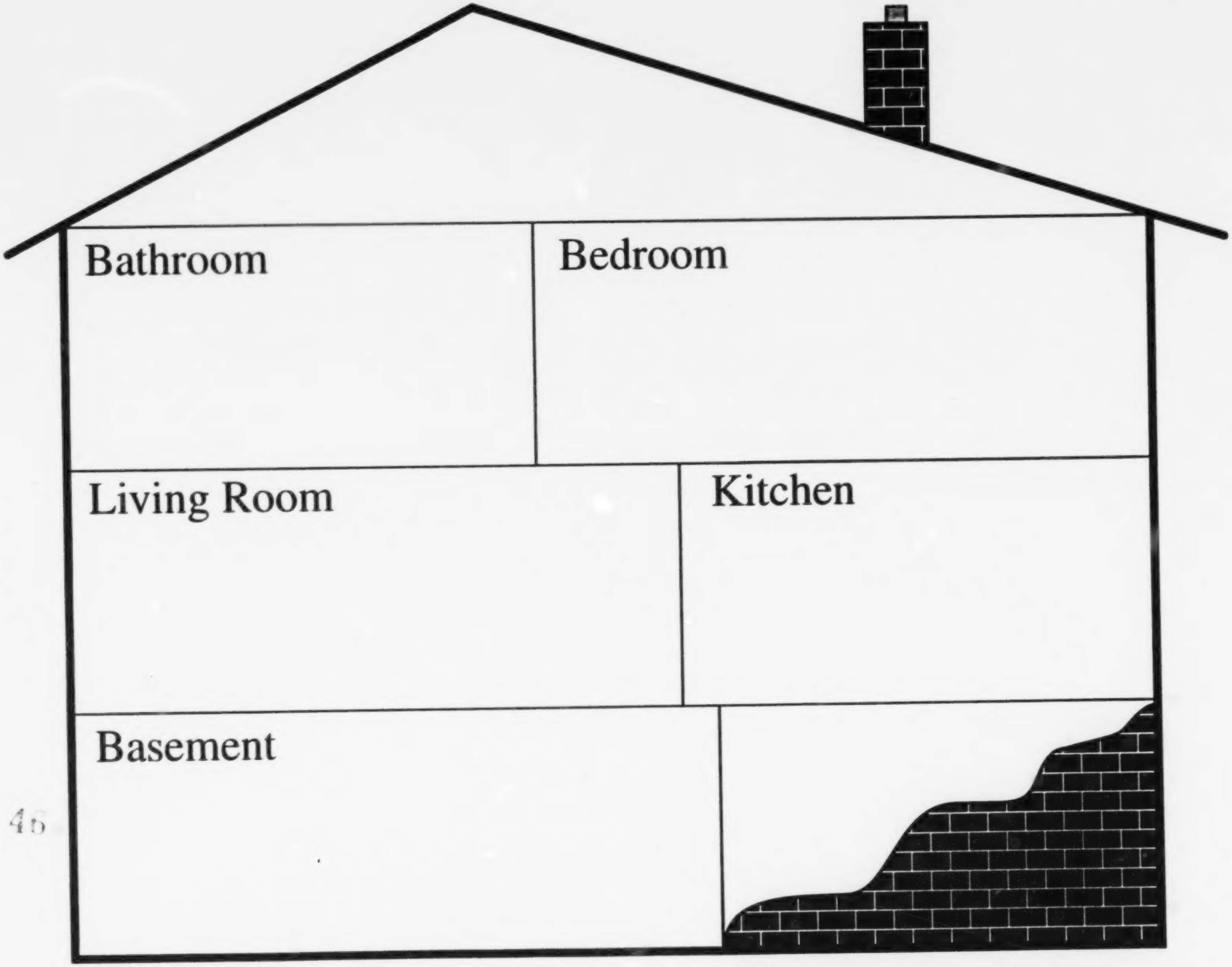
Wattage of Household Appliances



Name of item	Wattage	Number of hours of use per day	Watt-hours per day (wattage x # of hours used per day)

Fill in the estimated watt-hours per day for the items found in your home that are listed on the charts on the previous page.

Group ________


Bathroom
Bedroom
Living Room
Kitchen
Basement

How Do You Contribute to Ozone Pollution

TEACHER BACKGROUND

OBJECTIVES

- Students will analyze data related to their personal contribution to air pollution from electricity consumption.
- Students will use critical thinking skills to create a plan for reducing the contribution of automobiles to ozone pollution.

MATERIALS

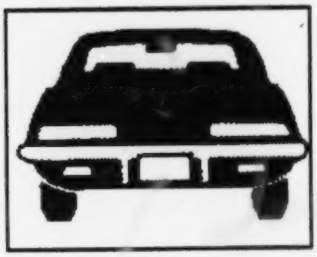
- handouts
- student's home
- calculator

SCIENCE SKILLS

- Data Analysis
- Problem Solving

This activity can be completed as a homework assignment, or as a class activity. If done as a class activity, the class can create a "composite home" with each small group identifying the approximate number and type of appliances located in their assigned room. The rooms can then be assembled into a composite home, and the calculations run accordingly.

Sources of Ozone-Related Pollution



Cars are a major source of ozone pollution.

Every time you turn on a light, watch television, or go somewhere in a car, you are adding more air pollution into the atmosphere. In most cases, we are able to produce electricity, travel in vehicles, and heat our homes because we burn coal, oil , or natural gas. *The burning of these fossil fuels is the main source of the compounds responsible for air pollution.*

Volatile Organic Compounds (VOC's)

An organic compound, generally speaking, is a compound that contains carbon. Some examples are octane, butane, and sugar. Volatile organic compounds are organic compounds that evaporate easily. VOC's come from vehicle exhaust, lawnmowers, oil-based paints, industrial plants, dry cleaners, printers, fuel spills, and certain other fumes. Poorly-tuned engines will release more VOC's than well-tuned ones. Catalytic converters reduce the amount of VOC's generated by automobiles. On sunny summer days when the air in a city is still, or not well-mixed, **volatile organic compounds can react with nitrogen oxides to form ozone.**

HIGHLIGHT

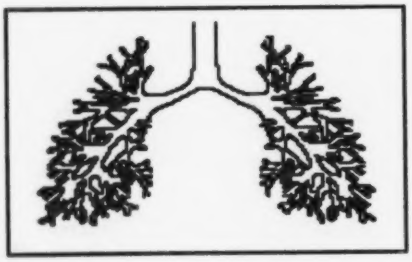
The burning of fossil fuels is the main source of the compounds responsible for air pollution.

Many VOC's have been classified toxic and carcinogenic (cancer-causing), and therefore unsafe to be in contact with in large quantities. Some health effects from overexposure to volatile organic compounds are dizziness, headaches, and nausea. Long-term exposure to certain VOC's, such as benzene, has also caused cancer, and eventually death.

Nitrogen Oxides

Stack emissions from the generation of electrical power and vehicle emissions from transportation result in the release of nitrogen oxides (NO_x) into the atmosphere. Both of these have to do with the combustion of fossil fuels. (Natural processes such as the action of bacteria in soil also release smaller amounts of nitrogen oxides into the environment.)

Nitrogen oxide compounds can react in the air to produce ozone and other harmful pollutants that lead to smog. In addition, nitrogen oxide compounds are themselves poisonous gases when present in high concentrations in the lower atmosphere. Nitrogen oxides can cause lung damage.



Lungs are susceptible to damage from nitrogen oxides and from ozone pollution.

Yearly Emissions of Nitrogen Oxides in the U.S.

10^6 Metric Tons/Year

	1977	1987
Transportation	10.1	8.4
Stationary Fuel Combustion (power plants/ industrial boilers)	14.3	10.3
Other industries	1.0	0.8

[1] *1977 data from: Wark, K. and C. F. Warner. 1981.* Air Pollution -Its Origin and Control, 2nd ed. *New York: Harper and Row.*

1987 data from: Godish, T. 1991. Air Quality, 2nd ed. *Chelsea, MI: Lewis.*

This chart shows emissions, or discharge into the atmosphere, of nitrogen oxides in metric tons. A metric ton is the same as 1000 kilograms.

QUESTION

Do gases have mass? Yes they do. Different gases have different masses. Some are heavier than others

Data Analysis

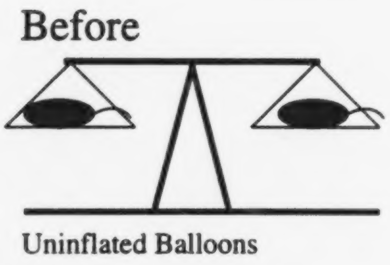
1. According to the table on nitrogen oxide emissions, have overall emissions of nitrogen oxides gone up or down from 1977 to 1987?
2. What are some sources of ozone pollution? What are some effects? Write down your answers on separate index cards. Put your name on the index cards and place them in the shoe boxes marked "Sources" and "Effects" at the front of the room.

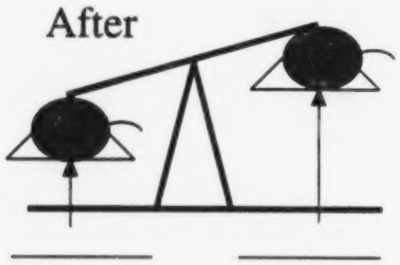
Example

Think what would happen if two identical balloons were filled with equal volumes of gas, but one was filled with carbon dioxide and the other was filled with oxygen.

A balloon is placed on each side of a pan balance. What do you think will happen? Which gas is heavier? How do you know?

Label the balloons in the "after" diagram.





Concept Mapping

Name: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

- Demonstrate an understanding of the relationships between concepts related to ozone.

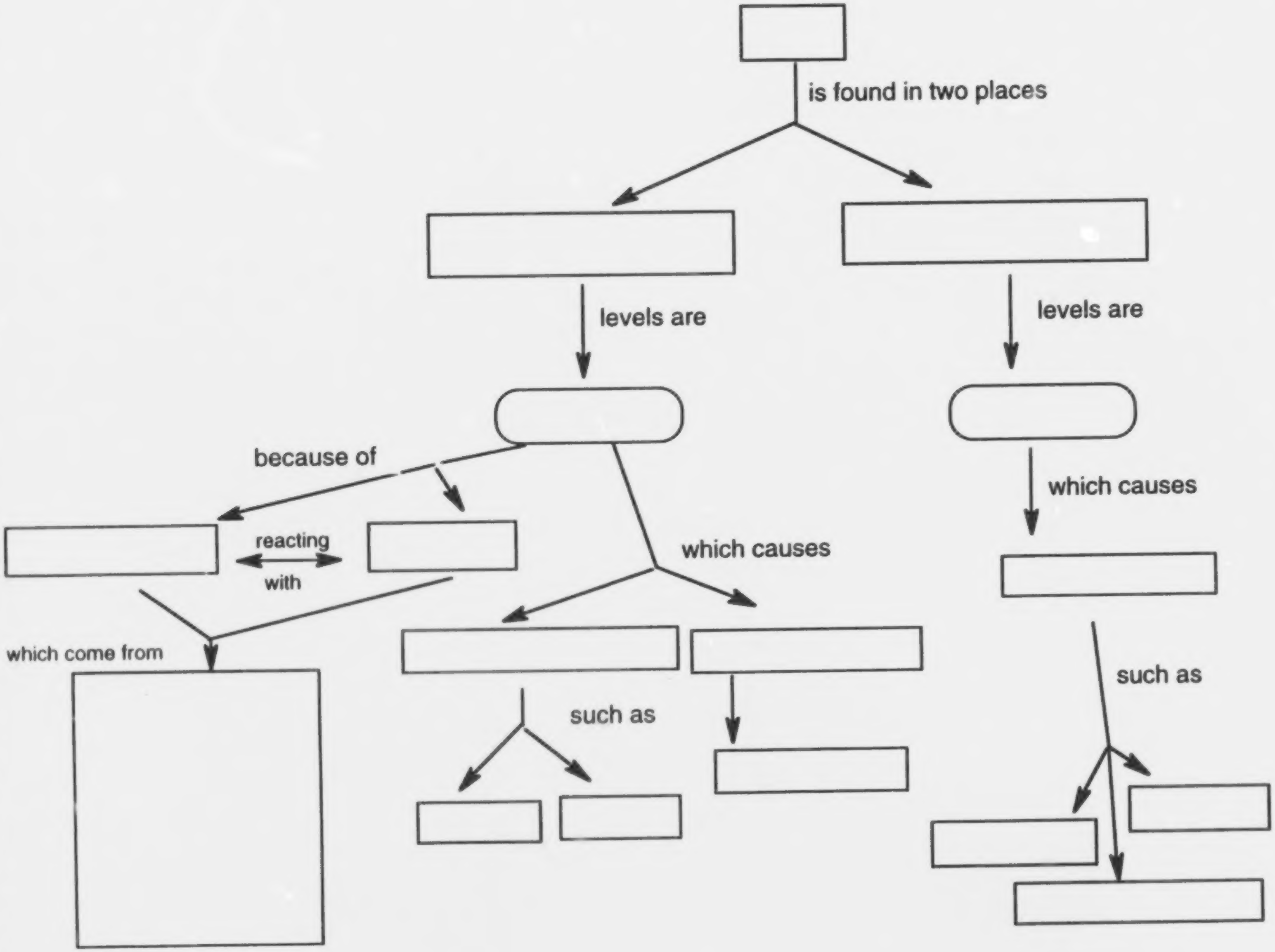
MATERIALS

- Ozone Concept Map Worksheet

Instructions:

Place the words below in the appropriate place in the ozone concept map worksheet.

cars
cataracts
damage to materials
decreasing
dry cleaners
electricity
fuel spils
health effects
health effects
immune deficiency
increasing
industrial plants
lawnmowers
lung damage
nitrogen oxides
nylon
oil-based paints
ozone
rubber
skin cancer
stratospheric ozone
tropospheric ozone
VOC's


is found in two places
levels are
levels are
because of
reacting
with
which causes
which causes
which come from
such as
such as

Concept Mapping

TEACHER BACKGROUND

OBJECTIVES

- Demonstrate an understanding of the relationships between concepts related to ozone.

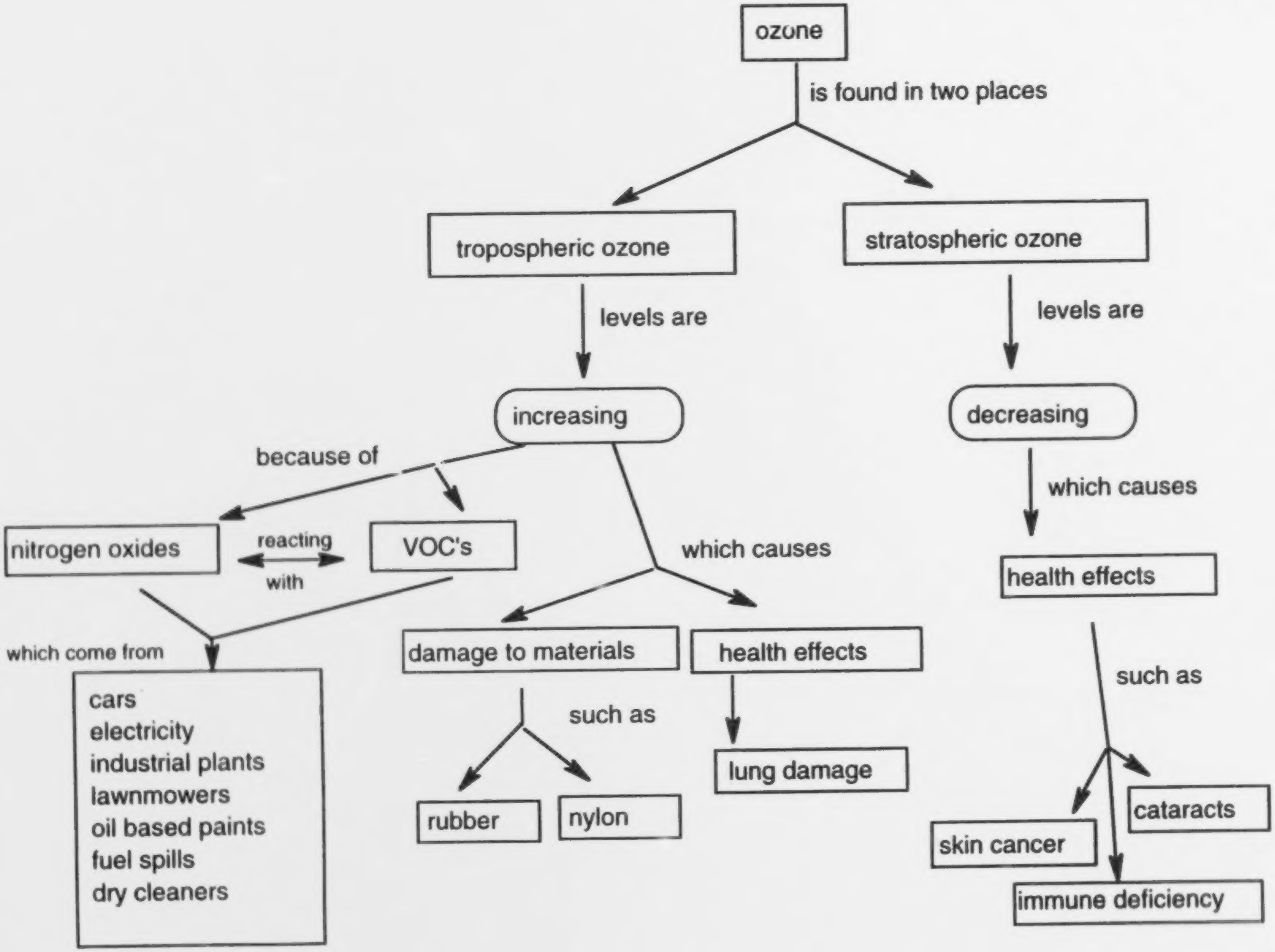
MATERIALS

- Ozone Concept Map Worksheet

SCIENCE SKILLS

- Critical Thinking

On the following page is the correctly filled in concept map.


ozone
is found in two places
tropospheric ozone
stratospheric ozone
levels are
increasing
levels are
decreasing
because of
nitrogen oxides
reacting with
VOC's
which come from
cars
electricity
industrial plants
lawnmowers
oil based paints
fuel spills
dry cleaners
which causes
damage to materials
such as
rubber
nylon
health effects
lung damage
which causes
health effects
such as
skin cancer
cataracts
immune deficiency

Effects On Materials

Name: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

- Observe, then compare and contrast the appearance of material exposed and unexposed to ozone.

MATERIALS

- nylon
- rubber
- paper
- copper
- limestone
- plastic
- cardboard

Introduction:

Your teacher will generate ozone in the classoom. In the space below, please describe how the ozone is being generated.

Procedure:

1. Before observing the materials set out by your teachers, rank the following materials on the line below according to how susceptible you think they are to ozone damage.

paper
plastic
cardboard
copper
nylon
limestone
rubber

easily damaged by ozone

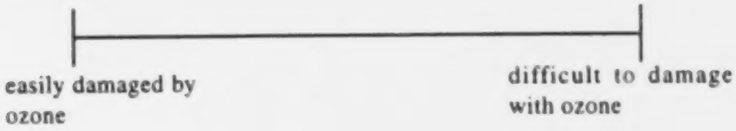
difficult to damage with ozone

2. You will be examining the materials listed above at workstations laid out by your teacher. Design a data collection sheet that will help you record your observations of the materials that have been exposed to ozone, and your observations of the same materials

that have not been exposed to ozone.

3. Examine the materials laid out at stations by your teacher. Compare and contrast the items exposed to ozone and unexposed to ozone. Do you notice any differences?
4. After observing the materials set out by your teachers, rank the following materials on the line below according to how susceptible you think they are to ozone damage.

paper
limestone
cardboard
copper
nylon
plastic
rubber


easily damaged by ozone
difficult to damage with ozone

Sample Data Collection Sheet

	Exposed to Ozone	Unexposed to Ozone
paper		
plastic		
nylon		
cardboard		
limestone		
rubber		
copper		

Effects On Materials TEACHER BACKGROUND

OBJECTIVES

- Students will observe, then compare and contrast the appearance of material exposed and unexposed to ozone.

MATERIALS

- 1000 ml Erlenmeyer flask
- Tesla Coil
- wire with alligator clips on each end
- copper wire
- Aluminum Foil
- dissecting scopes
- labels
- nylon
- rubber
- paper
- copper
- limestone
- plastic
- cardboard

SCIENCE SKILLS

- Experimental Design

Notes and Expected Outcomes:

In this lab experience, you can use the sample data collection sheet provided, or have students design their own. You can also extend brainstorming with the class a list of materials to text. Students can bring in samples. They will need to bring in two identical items.

Preparation:

1. Shape one end of a copper wire into a coil, and insert it into a "Twistit" rubber stopper with stopped up holes (if your stopper has holes, seal the holes with paraffin or wax). The portion of the wire formed into a spiral should be at least 6 inches in length to yield sufficient production of ozone.
2. Prepare two sets of each type of material. Examine them beforehand to see that they are as identical as possible. Place one of each type material inside the flask, and the twin of each outside the flask.
3. Fill the flask with some oxygen gas. (The oxygen level doesn't need to be at 100%, but a higher than normal level will facilitate the reaction.)
4. Put laboratory film over the top of the stopper.
5. Wrap the bottom half the flask with aluminum foil. Also wrap the rubber stopper with tin foil to prevent combustion from the high oxygen level.
6. It is best to ground the aluminum foil. Using a wire with alligator clips at each end, clip one end to the foil and the other to a faucet or water pipe.
7. Touch the Tesla coil to the copper wire for at least 2 minutes.
8. Leave the materials in the flask overnight. Set out identical materials outside the flask to use as controls.

Reference:
Chan, Alan, Adele Gomez, Patricia Noel, & Ron Ulrich. 1991. Chemistry in the Environment *Woodrow Wilson National Fellowship Foundation*

SAFETY NOTE

- Goggles should be used for all laboratory work. Gloves may be recommended.
- Care should be taken to properly dispose of all chemicals used in this activity.
- Gases generated should be released with care (under a fume hood if possible).
- There is an electrical hazard due to high voltage. Keep the Tesla coil unplugged until ready for use and unplug immediately when finished.
- Keep the flask containing ozone at arm's length, and avoid breathing the gas.
- Inhaling small quantities of ozone can irritate the lungs.
- As a basis for comparison, the ozone National Ambient Air Quality Standard is 0.12 ppm (by volume) for a one-hour time period.
- To avoid the risk of an explosion- do not add any substances to ozone other than those described here.

9. Ask students to complete steps 1 and 2 on the day before the lab. After reviewing the data collection sheets they have designed, determine whether to have them use their own data collection sheets or the pre-designed sheet attached.

10. Set up the materials around the room in stations with each material both exposed to ozone and unexposed to ozone at a different station. Label each item appropriately. Arrange each of the materials so that they can be viewed under a dissecting scope.

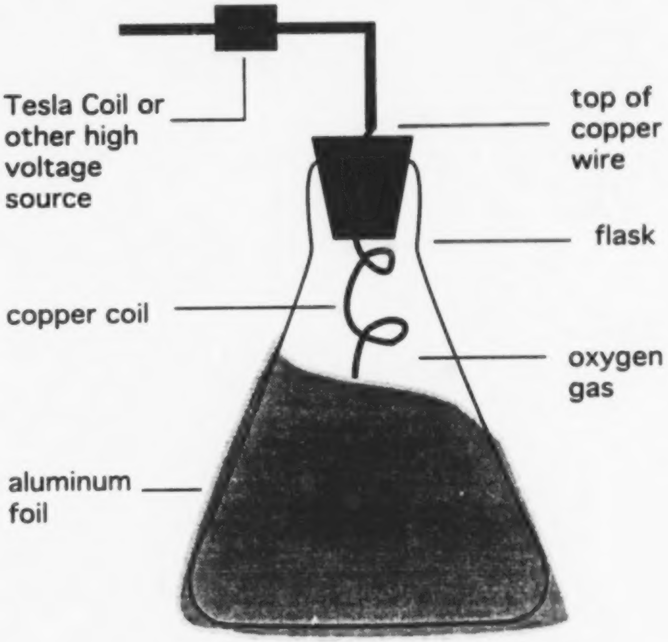
Background Information

In this experiment, electrons generated by the Tesla coil at the copper coil move though the gas towards the grounded aluminum foil. However, they collide with molecular oxygen in the gas to form oxygen radicals. The oxygen radicals subsequently react with O_2 to form ozone.

Disposal

After preparing the materials, dispose of the polluting gases by filling the flask with water in a fume hood.

Setup



Fraying Fabrics

Name: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

Students will:

- Plan strategy for representative sampling of air.
- Observe the effects of air pollutants on a specific material: nylon.
- Design a controlled experiment.
- Observe qualitatively and quantitatively.
- Modify their experimental designs based on experience.
- Interpret their results.
- Demonstrate understanding of reasonable error.

MATERIALS

- scissors
- plastic slide mounts (3 or more per person)
- glue
- thread or fishing line
- masking tape
- nylon stocking pieces
- 3 x 5 index cards
- magnifying glass or micro scope

Introduction:

The effects of ozone and other air pollutants on health, vegetation, and materials can be serious. In this activity you will make some observations about the longer-term effects of air pollutants on materials.

Instructions

Your task is to design a properly controlled experiment to study the effects of ozone and other air pollutants on rubber (as in rubber band) and on a synthetic fabric, nylon (as in stockings) over a three-week period.

At the end of that period you will collect your samples, bring them in, and observe then under a dissecting scope in addition to your once-a-week observations for three weeks. Be sure to take careful initial observations (and record them also) so that your final observations can be compared. Remember that materials under stress are more likely to show the effects of pollutants.

Your report sheet should show your initial experimental plan, including your control, with both the nylon and rubber band mounted on the slides, and detailed description of each site chosen for each slide. In addition you should include your observations and other data, microscopic observations (even drawings), and your explanation of your conclusions. You will also be graded on the creativity of your choice of sites.

Questions

1. What areas of the city are most likely to be exposed to ozone pollution?
2. Where will you place your samples?
3. How can you help prevent vandalism from unduly affecting your experiment?
4. How will you know that the effects you observe are the result of pollutants, and that your samples would not get that way over a three week period without being exposed to pollutants?
5. The **control** is a sample that is not exposed to ozone pollution, so that changes in the control sample can be compared to changes in the samples exposed to ozone pollution. Where will you place your control?
6. How will you prepare your samples? Material under stress is more likely to show damage by air pollutants. How can you maximize the effects of ozone and other air pollutants on the material?
8. What qualities of the materials can you observe before, during, and at the end of the experiment?
9. You will need to design a data collection sheet to record your data. What should that data collection sheet look like?

Sample Data Sheet

	Sample #1	Sample #2	Sample #3	Sample #4
Observation #1 (before setting out)				
Observation #2				
Observation #3				
Observation #4				

Sample Data Sheet 2

	Sample #1	Sample #2	Sample #3	Sample #4
Site:				
Location				
Description of area				
Possible pollution sources in the area				
Collector:				
Date, day and time set out				
Date, day and time of observation #2				
Date, day and time of observation #3				
Date, day and time of observation #4				

Fraying Fabrics

TEACHER BACKGROUND

OBJECTIVES

Students will:

- Plan strategy for representative sampling of air.
- Observe the effects of air pollutants on a specific material: nylon.
- Design a controlled experiment.
- Observe qualitatively and quantitatively.
- Modify their experimental designs based on experience.
- Interpret their results.
- Demonstrate understanding of reasonable error.

SCIENCE SKILLS

- Experimental Design

Notes and expected outcomes

Most students will develop a plan in which they stretch the nylon and rubber bands over slide mounts and glue the cover to the slide mount in place. If the materials are placed loosely rather than tautly on the slide mount, the effects of air pollutants will be less noticeable. The nylon and rubber should be examined carefully, and careful notes taken as to the initial color, odor, texture, and elasticity of the sample. Each sample should be examined for any irregularities in the weave or threads. Labeling is important to avoid a large percentage of the samples being lost during the observation period. "Please do not disturb. Air pollution experiment in progress. Thank you!" is an effective label. Placing more than one sample in the same general area will also help protect from vandalism if one is disturbed. Whatever the number of samples prepared, one sample should be set aside in a clean, dark, dry location as the control. The other samples should be hung or mounted in locations where exposure to air pollutants is maximized but exposure to extreme heat is minimized. As a class project, students could coordinate their choices so that a wider range of locations are examined.

The observing area can be increased if larger pieces of stocking are stretched and glued on wooden embroidery hoops. Some students may wish to extend the time of observation so that effects are more noticeable, particularly if samples have been located in a relatively clean environment. Other loosely woven fabric may be used.

Small group brainstorming followed by class discussion of the answers to the question at the bottom of the student page would be an excellent way to guide students unfamiliar with how to design an experiment.

If students are not experienced at designing a format for recording their data, you can ask them to create one and turn it in as a separate assignment. Once they have given it their best effort, you can either choose to allow them to use what they have designed, or hand out the sample data collection sheet for them to use.

MATERIALS

- scissors
- plastic slide mounts (3 or more per person
- glue
- thread or fishing line
- masking tape
- nylon stocking pieces
- 3x5 index cards
- magnifying glass or micro scope

Upon completion of the lab, you could ask students to complete the following assignment in preparation for the slide show project.

"Answer the following question on an index card with information that you learned from this lab. Put your name on your card and deposit it in the shoebox marked 'Effects' in the front of the room. 1) Explain how ozone pollution can affect materials."

Suggested Scoring Check Sheet

[Expected Maximum of 15 points; 5 points of Extra Credit]

The procedure is appropriate and complete.

_____________**(5 points maximum)**

Observations and data are well organized and easily understood.

_____________**(5 points maximum)**

Conclusions are drawn and are based on available evidence.

_____________**(5 points maximum)**

Extra credit work is present, such as investigating the chemical reactions that could account for the observed changes, redesigning the experiment for the future, sophisticated error analysis. **(+5 points maximum)**

In the News

The article headlines listed below have appeared in the magazines indicated. In the column on the far right, indicate whether the article headline is referring to ozone pollution in the lower atmosphere (the troposphere) or ozone depletion in the upper atmosphere (the stratosphere). Mark headlines related to tropospheric ozone with a "T". Mark headlines related to stratospheric ozone with an "S". Use the "Ozone Scavenger Hunt" to help you determine the correct answers. Justify your answers on a separate peice of paper.

Magazine	Article	Ozone Location
Newsweek	Holes in the Ozone Treaty	
Science	Urban Ozone Control and Atmospheric Reactivity of Organic Gases	
Science News	New source identified for Mexico City Smog	
New York Times	GOP bills aim to delay ban on CFC's in O_3 dispute	
Architectural Record	VOC Regulations: Change is in the Air	
Unesco Courier	Clean Driving a Green Dream	
New York Times	Freon Smugglers Find Big Market	
Current Health	Want to Clear the Air? Hop on the Bus	
American Health	Lung Damage: Pollution May Rival Smoking	
Science	Antarctic Ozone Fail to Recover	
Audubon	The Ozone Below	
Consumers Resources Magazine	Urban Smog: How Bad a Health Hazard?	

In the News

TEACHER BACKGROUND

This excersize can also be done as a class by cutting out the titles and placing them on cards. Students place the cards in a location that corresponds with troposphere or a location that corresponds with stratosphere. The class justifies the locations in group discussion.

Magazine	Article	Ozone Location
Newsweek	Holes in the Ozone Treaty	S
Science	Urban Ozone Control and Atmospheric Reactivity of Organic Gases	T
Science News	New source identified for Mexico City Smog	T
New York Times	GOP bills aim to delay ban on CFC's in O_3 dispute.	S
Architectural Record	VOC Regulations: Change is in the Air	T
Unesco Courier	Clean Driving a Green Dream	T
New York Times	Freon Smugglers Find Big Market	S
Current Health	Want to Clear the Air? Hop on the Bus	T
American Health	Lung Damage: Pollution May Rival Smoking	T
Science	Antarctic Ozone Fail to Recover	S
Audubon	The Ozone Below	T
Consumers Resources Magazine	Urban Smog: How Bad a Health Hazard?	T

Slide Show

Name: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

- Conduct research and communicate the results of studies on ozone pollution through the production of a computer slide show.

MATERIALS

- Computers
- Slide show program, such as Microsoft Works 4.0
- "Ozone Hunt" web pages on the computer, or point to:http://biodec.wustl.edu/EnvSci/Ozone/ozone.html

Instructions:

1. Each team of students is assigned or selects one of the following topics:

   Location of ozone in the atmosphere:
   Where is ozone located in the atmosphere? How can ozone in one location be distinguished from the other?

   Sources of ozone pollution:
   Discuss and describe the sources of ozone pollution.

   Effects of ozone pollution:
   Explain how ozone pollution can affect people, plants and things.

   Solutions to ozone pollution:
   How can ozone pollution be reduced?

2. Collect information on index cards from previous ozone activities, and by vewing the "Ozone Scavenger Hunt".
3. Organize an outline of your subtopic, using information gathered.
4. Divide your outline and set of index cards into three components, one for each member of the team. Submit your proposed outline and divisions.
5. Each individual will design at least one slide to communicate his or her assigned information to a younger audience.
6. The first draft slides will be assembled together into a class show. Slides are viewed and critiqued by the class as a whole.
7. Make revisions/improvements on your slide or slides based on classroom critique.
8. View slides produced from all the classes, and select the best ones to include in the final product.

Slide Show

TEACHER BACKGROUND

OBJECTIVES

- Students will conduct research and communicate the results of studies on ozone pollution through the production of a computer slide show.

MATERIALS

- Computers
- Slide show program, such as Microsoft Works 4.0
- "Ozone Hunt" web pages on the computer, or point to: http://biodec.wustl.edu/EnvSci/Ozone/ozone.html

SCIENCE SKILLS

- Accessing Information
- Communicating Results

To facilitate your students' research on ozone, point the web browser to http://biodec.wustl.edu/EnvSci/Ozone/ozone.html.

If your school computers do not have Internet access, you can request the Ozone Web Pages and ozone slide show template on disk. Contact:

Karla Goodman Wilson
Washington University
#1 Brookings Dr. Campus Box 1229
St. Louis, MO 63130

E-mail:
wilson@wustl.biodec.edu

Creating a Slide Show Template

The best way to have your students create a slide show is to make a template slide show that they can work from. The template provides structural guidance as well as creative ideas.

Below are instructions for setting up a slide show template in Microsoft works 4.0. Other slide show templates will be similar. Try changing fonts and colors, creating new text fields, creating transparent backgrounds for text, and creating your own pictures.

1. Start up Microsoft Works
2. At the opening dialog box choose Works Wizards
3. Choose Presentation
4. Answer the questions presented to you about your slide show
5. Choose Create It

6. When it's done it tells you to read the Presentation Tips document. If you click on Print, it will print it out for you. Or you can choose Done and it will simply open the document on top of your new slide show so you can read it and then close it.

7. Go through the slides marking each one up to be a template for your students. Add more slides as necessary.

8. Save frequently!

9. When you are finished, save it normally, then choose Save As from the file menu. Change the file format to Stationary. Then give it a different name (you could simply append student or template to the previous name.) Save it to your students folder in the documents folder.

Following is a highly structured slide show template created by one teacher. You can choose to make your template more or less structured as desired.

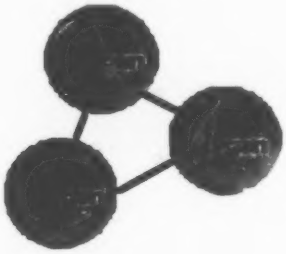
Ozone - The Tropospheri Pollutant

Type your name(s) here

Type today's date here

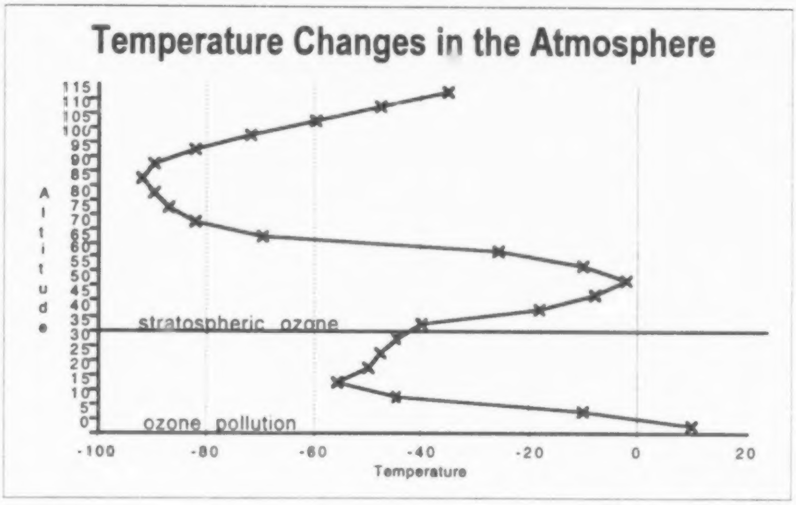
Definition

write in this space your definition and composition of ozone



Location

In this space tell the locations and importances of "good" ozone and "bad" ozone



In this space tell the importance of this graph

Sources of Ozone

- In this space state the main source of air pollution
- In this space define VOC's and give 3 sources of VOC's
- In this space define nitrogen oxides and tell where they come from

Both VOC's and nitrogen oxides react with one another in the presence of sunlight to form ozone.

How Do You Contribute?

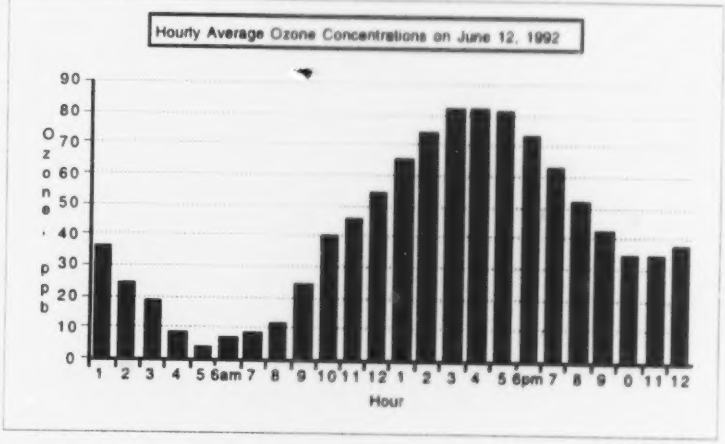
Classroom surveys were done at home and at school. The following results were collected:

*** In this space give the % from your surveys for**
a) using gas powered lawnmowers
b) barbequeing with charcoal and lighter fluid
c) rarely or never carpooling

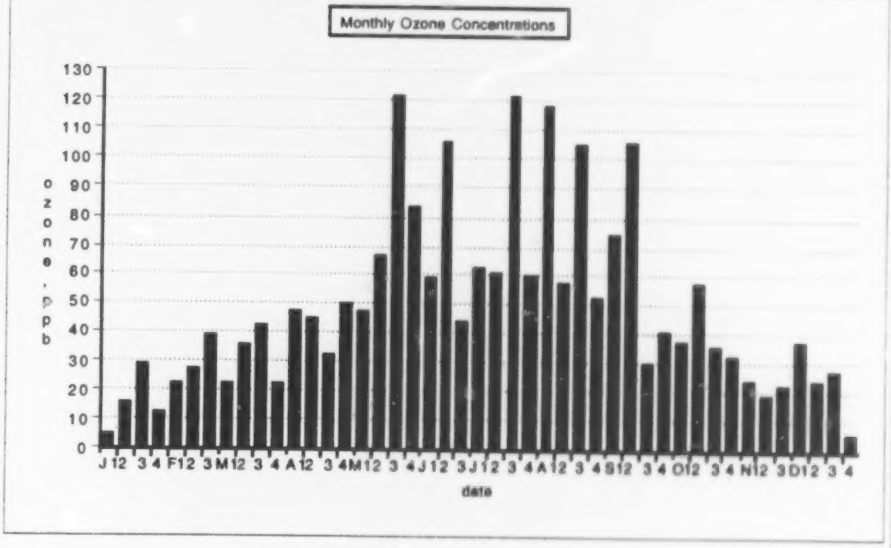
*** 92% of households produce 0.4 kg of nitrogen oxide each day**

Conditions for Formation

In this space tell what this graph represents.



In this space tell what is indicated by the graph below



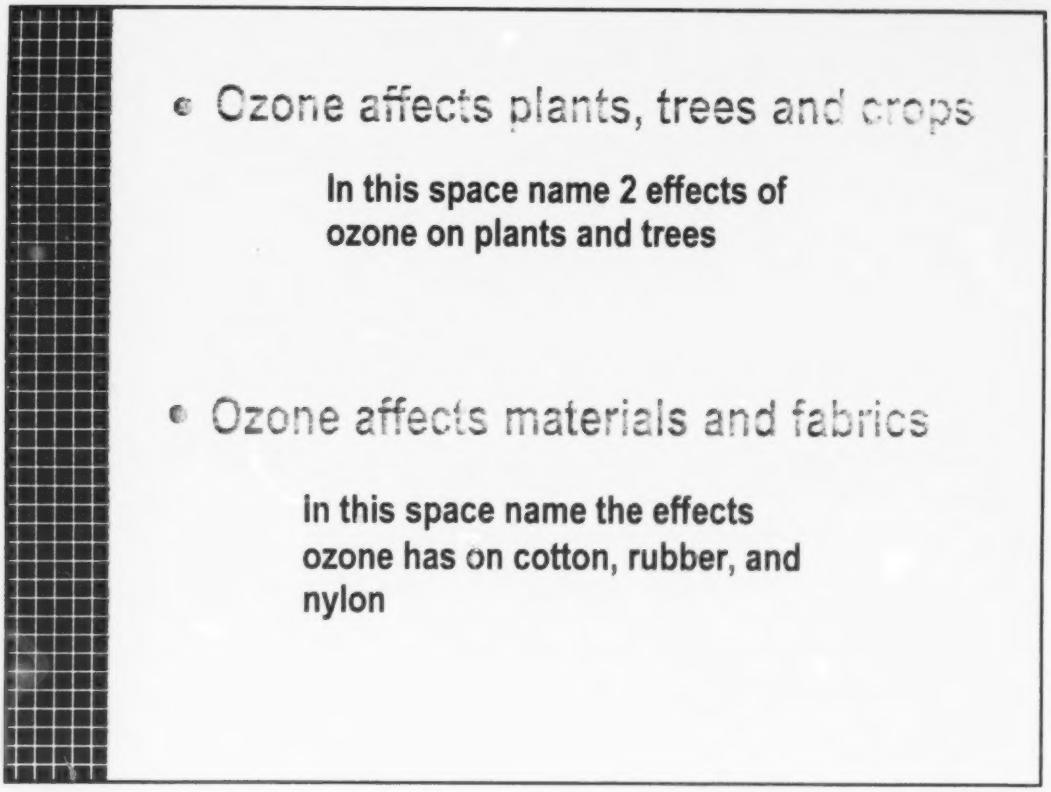
Students determined that the highest daily ozone levels appeared between 3 and 5 p.m. Highest yearly levels occurred during the summer months. We concluded that 3 conditions best promote ozone formation. . .

In this space list the 3 conditions that best promote tropospheric ozone formation

Effects of Ozone Pollution

Ozone affects human health

In this space list 6 health problems caused by ozone pollution

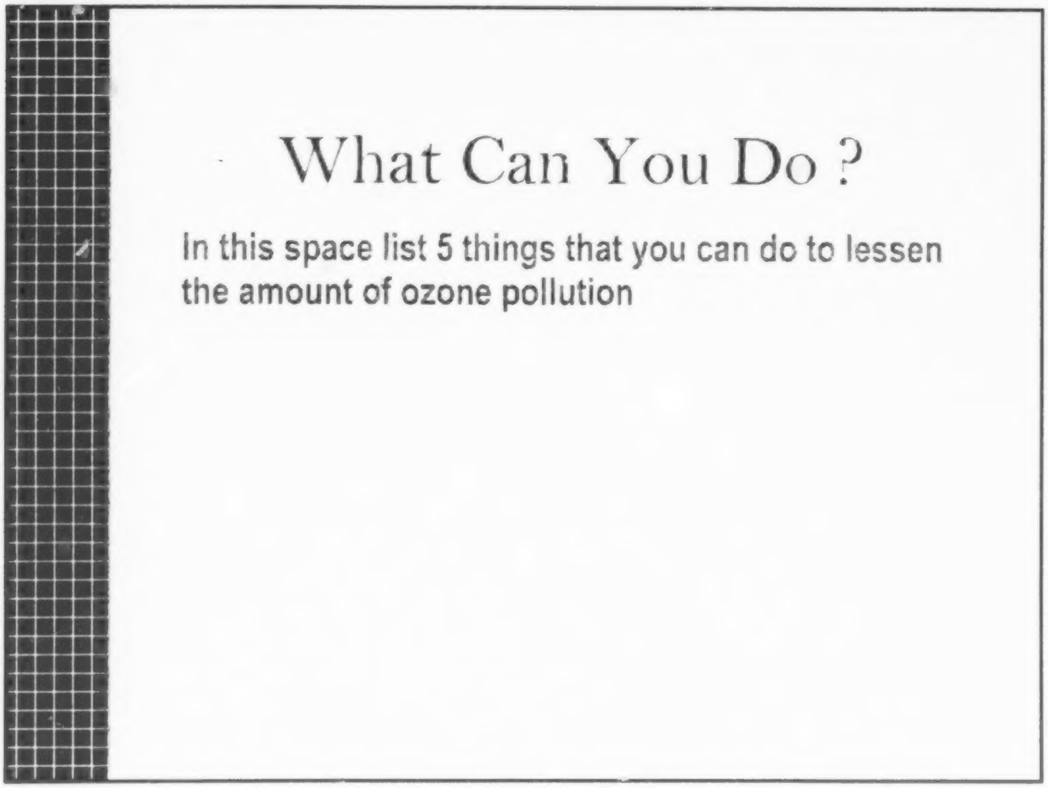


- Ozone affects plants, trees and crops

In this space name 2 effects of ozone on plants and trees

- Ozone affects materials and fabrics

In this space name the effects ozone has on cotton, rubber, and nylon



What Can You Do ?

In this space list 5 things that you can do to lessen the amount of ozone pollution

Ozone

Does It Affect Me?

CHEMISTRY UNIT

Science Skills

The following science skills have been identified as central to student success in science learning:

Laboratory Procedures: Instrumental techniques, analytical methods.

Experimental Design: Scientific method, decision-making, sampling, controls.

Data Analysis: Making comparisons/ connections, statistical analysis, evaluating the impact of results on society.

Accessing Information: Computer search, accessing current data over Internet.

Critical Thinking: Problem solving, reasoning, synthesis, evaluation

Systems Modeling: Simulations, designing physical models

Communicating Results: writing, speaking, creating presentations.

Learning Cycle

This unit has been structured according to a learning cycle model. The basic components of the learning cycle are as follows:

Engage: Create interest, generate curiosity, and identify students' preconceived notions.
Explore: Provide opportunity to observe and test ideas.
Explain: Present definitions and concepts.
Elaborate: Students apply ideas to a new situation.
Evaluate: Assess student knowledge and skills.

Cooperative Learning

Studies indicate that girls attain higher achievement when taught science in cooperative groups (Berliner, 1992). Some of the activities in this unit are designed in a cooperative learning format. This format includes the following components:

Positive Interdependence: Examples of techniques that promote positive interdependence are using one paper or one set of materials for the group, giving each member a separate job or role, giving all group members the same reward, or giving each person only part of the information .

Individual Accountability: Examples of techniques that promote individual accountability include quizzing or testing individually, random selection of a paper from the group for grading, random oral quizzing of group members, individual homework, or asking for individual signatures.

Criteria for Success: Clearly identify the criteria for success for the lesson and communicate it to students.

Interpersonal skills: Identify, explain, demonstrate, teach, practice, monitor, and/or evaluate one or more social skills. (See the "Investigating Ozone" activity for a list of interpersonal skills that could be addressed.)

Main Concepts Presented In this Unit

1. Describe the series of chemical reactions that leads to ozone pollution and smog.
   $N_2 + O_2 \rightarrow 2NO$
   $2NO + O_2 \rightarrow 2NO_2$
   $NO_2 + \text{sunlight} \rightarrow NO + O$
   $O + O_2 + M^* \rightarrow O_3 + M^*$
   $NO_x + O_3 + \text{hydrocarbon} + \text{light} \rightarrow$ photochemical smog + peroxyacetyl nitrate (PAN)

2. Identify the solute and solvent in a homogeneous mixture.

3. Measurements of concentrations of very dilute solutions, such as ozone in the atmosphere, are often stated in parts per million or parts per billion. Create a solution of one part per million, and an operational definition of ppm.

4. Describe how stratospheric ozone absorbs harmful ultraviolet light.

5. Describe the series of chemical reactions that leads to ozone depletion.
   $Cl + O_3 \rightarrow ClO + O_2$
   $ClO + O \rightarrow Cl + O_2$

6. List three ways that reaction rates are influenced and how each can be applied to ozone depletion.

   A. The nature of reactants influences reaction rates. Reactions that include stable molecules have slower reaction rates. Reactions that include unstable molecules have faster reaction rates. CFC's are stable molecules and do not dissacosiate easily until they reach the stratosphere. A chlorine atoms is unstable, allowing it to destroy several thousand ozone molecules.
   B. An increase in temperature increases reaction rates. The Spring sunrise over Antarctica in October increases temperature which increases the rate of ozone depletion.
   C. A catalyst can increase the speed of a reaction without becoming depleted. Chlorine behaves as a catalyst in the process of ozone depletion.

Getting Started

Two activities from the Environmental Science unit are recommended to provide a framework for introducing the study of ozone. ""Investigating Ozone" draws out the preconceived ideas of your students. "Layers of the Atmosphere" provides a context for studying the different effects of ozone located in two different places in the atmosphere.

Also included with this unit are a multiple choice test, an attitude survey, and an essay question. These assessment tools can be administered as pre and post tests for the unit to help assess student learning.

Unit Outline According to Learning Cycle and Science Skills

Activity	Concept	Learning Cycle	Science Skills
A. Smog in a flask	1	Engage	Critical Thinking
B. Graphing ozone levels	1,3	Explore	Data Analysis
C. Formation of photochemical smog - active response	1	Explain	Systems Modeling
D. Out of sight	2,3	Elaborate	Laboratory Procedures
E. Article Analysis	2,3	Engage	Critical Thinking
F. St. Louis Ozone Task Force	1,3	Elaborate	Data analysis Problem Solving Communicating
G. Scientist role play (Snowmass Showdown)	4-8	Explain	Communicating Results
H. Analysis of ozone depletion data	4,5	Elaborate	Data Analysis
I. Kinetics grid problems	6-8	Evaluate	Critical Thinking

Video Resouces

If you would like to supplement your lessons with ozone videos, the following are recommended:

The video "Ozone: The Hole Story" is approximately one hour long and can be obtained for up to five days by calling 1-800-243-6877.

The video "Hole in the Sky: The Ozone Layer" is 52 minutes, and can be purchased from Films for the Humanities & Sciences for $89.95. Call 1-800-257-5126.

Multiple Choice Questions

Name: ____________________

Date: ____________________

Period: ____________________

1) Which of the following is a solution?

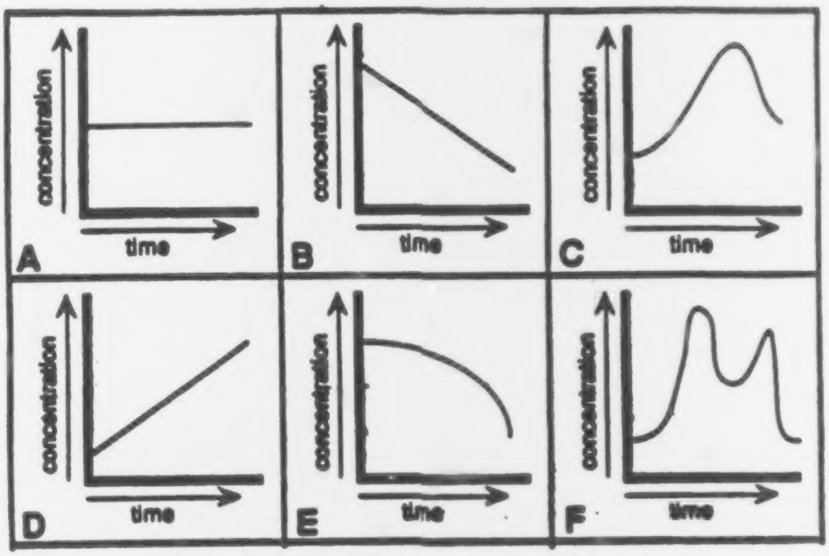
A. carbon
B. ozone
C. smog
D. the unpolluted atmosphere
E. muddy water
F. smoke

2) .12 ppm ozone is the same as

A. .012 ppb ozone
B. .0012 ppb ozone
C. .00012 ppb ozone
D. 1.2 ppb ozone
E. 12 ppb ozone
F. 120 ppb ozone

3) Which graph in the chart below best represents daily ozone fluctuations in the lower atmosphere? (Circle the appropriate corresponding letter.)

A. B. C. D. E. F.



4) Which graph in the chart above best respresents the data on the table below? (Circle the appropriate corresponding letter.)

A. B. C. D. E. F.

conc., ppm	299	259	219	179	139	99	59
time, min.	0	1	2	3	4	5	6

Multiple Choice Continued

Name: ______________________

Date: ______________________

Period: ______________________

5) The solute is. . .

A. a homogenious mixture.
B. the solvent plus the solution.
C. the subtance into which the solvent is dissolved.
D. an aqueous solution.
E. always in liquid form.
F. the substance that is dissolved.

6) Which of the following could NOT increase the rate of a reaction?

A. temperature
B. catalyst
C. surface area
D. nature of the reactants
E. chemical sink
F. concentration

7) Which of the following is a stable species?

A. Cl
B. ClO
C. CCl_2F_2 (a CFC)
D. O_3
E. $O\cdot$
F. None of the above

8) The rate of a reaction is. . .

A. the speed of reaction divided by the number of molecules.
B. how hot the reaction gets.
C. a measure of the concentration of molecules in a reaction.
D. the temperature of the reactants divided by the temperature of the products.
E. how fast a reaction takes place.
F. none of the above.

9) Which of the following behaves as a catalyst in the process of stratospheric ozone depletion?

A. chlorine atoms
B. chlorofluorocarbons
C. chlorine monoxide
D. chlorine molecules
E. chlorine nitrate
F. oxygen

10) As the temperature at which a reaction takes place increases, the rate of the reaction. . .

A. will increase
B. will decrease
C. will stay the same
D. cannot be determined
E. all of the above
F. none of the above

Multiple Choice Answers

Name: ____________________

Date: ____________________

Period: ____________________

1) Which of the following is a solution?

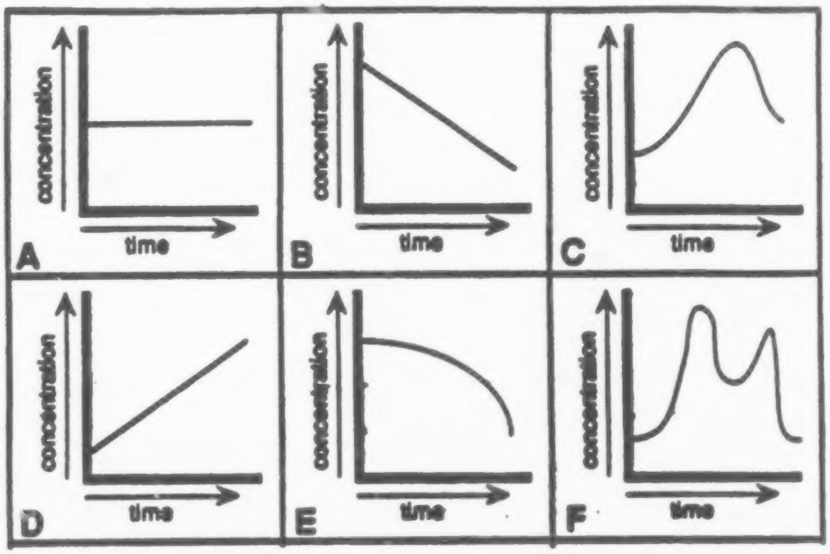
A. carbon
B. ozone
C. smog
[✓ D.] the unpolluted atmosphere
E. muddy water
F. smoke

2) .12 ppm ozone is the same as

A. .012 ppb ozone
B. .0012 ppb ozone
C. .00012 ppb ozone
D. 1.2 ppb ozone
E. 12 ppb ozone
[✓ F.] 120 ppb ozone

3) Which graph in the chart below best represents daily ozone fluctuations in the lower atmosphere? (Circle the appropriate corresponding letter.)

A. B. [✓ C.] D. E. F.



4) Which graph in the chart above best respresents the data on the table below? (Circle the appropriate corresponding letter.)

A. [✓ B.] C. D. E. F.

conc., ppm	299	259	219	179	139	99	59
time, min.	0	1	2	3	4	5	6

Multiple Choice Answers (cont.)

Name: ____________________

Date: ____________________

Period: ____________________

5) The solute is. . .

A. a homogenious mixture.
B. the solvent plus the solution.
C. the subtance into which the solvent is dissolved.
D. an aqueous solution.
E. always in liquid form.
[✓ **F.**] the substance that is dissolved.

6) Which of the following could NOT increase the rate of a reaction?

A. temperature
B. catalyst
C. surface area
D. nature of the reactants
[✓ **E.**] chemical sink
F. concentration

7) Which of the following is a stable species?

A. Cl
B. ClO
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E. $O\cdot$
F. None of the above

8) The rate of a reaction is. . .

A. the speed of reaction divided by the number of molecules.
B. how hot the reaction gets.
C. a measure of the concentration of molecules in a reaction.
D. the temperature of the reactants divided by the temperature of the products.
[✓ **E.**] how fast a reaction takes place.
F. none of the above.

9) Which of the following behaves as a catalyst in the process of stratospheric ozone depletion?

[✓ **A.**] chlorine atoms
B. chlorofluorocarbons
C. chlorine monoxide
D. chlorine molecules
E. chlorine nitrate
F. oxygen

10) As the temperature at which a reaction takes place increases, the rate of the reaction. . .

[✓ **A.**] will increase
B. will decrease
C. will stay the same
D. cannot be determined
E. all of the above
F. none of the above

Essay Question

Name: ______________________

Date: ______________________

Period: ______________________

Discuss the chemistry of ozone in the atmosphere. Include in your answer as many chemical pathways as you can think of for the formation, reactions and destruction of ozone. Discuss how the concentration of ozone in the atmosphere may affect human activity.

Attitude Survey

Name: ______________________

Date: ______________________

Period: ______________________

1. **I like studying about the environment.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

2. **I can help my family better understand environmental issues.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

3. **Understanding chemistry is necessary for understanding environmental issues.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

4. **I believe that I can apply what I have learned in chemistry class to other situations.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

5. **This class has gotten me curious about environmental problems.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

6. **I am interested in studying about environmental issues.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

7. **I talk about what we are learning in chemistry with my family.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

8. **The chemistry of ozone is a complex issue.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

9. **I talk about what we are learning in chemistry with my friends.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

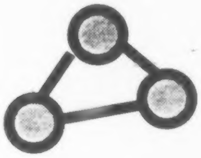
10. **The information that I am learning in class will be useful to me in the future.**

strongly agree	mildly agree	neutral	mildly disagree	strongly disagree
1	2	3	4	5

Part 1

Tropospheric Ozone

Smog In A Flask



Names: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

- Observe the results of the interaction of ozone and organic compounds.

MATERIALS

- 1000ml Erlenmeyer flask
- Tesla Coil
- wire with alligator clips on each end
- copper wire
- Aluminum Foil
- dissecting scopes
- lemon peel

Answer the following questions together with your partner:

1. What do you predict will occur when your teacher generates ozone and adds a lemon peel?

2. When your teacher performs the demonstration, record your observations.

3. Explain what you have observed.

4. The following was an actual e-mail message received. How would you respond to Don? If air pollution alerts are because of the "brown stuff" and ozone is clear, why should we be concerned about ozone?

> Hi, I kinda feel that ozone is getting a bumb rap. I sort of agree with the upper atmosphere side, ozone shields the UV from us. But the lower one I really question. If you go outside after a real strong thunder storm it smells fresh and clean. That's ozone at work. Now as for the California SIG alerts due to ozone??? The stuff there is oily and brown, but ozone is clear?
>
> Just my observations. Don

Smog In A Flask

TEACHER BACKGROUND

OBJECTIVES

- Students will observe the results of the interaction of ozone and organic compounds.

MATERIALS

- 1000ml Erlenmeyer flask
- Tesla Coil
- wire with alligator clips on each end
- copper wire
- Aluminum Foil
- dissecting scopes
- lemon peel

Procedure

1. Shape one end of a copper wire into a coil, and insert it into a "Twistit" rubber stopper with stopped up holes (if your stopper has holes, seal the holes with paraffin or wax). The portion of the wire formed into a spiral should be at least 6 inches in length to yield sufficient production of ozone.
2. Fill the flask with some oxygen gas. (The oxygen level doesn't need to be at 100%, but a higher than normal level will facilitate the reaction. The demo will also work with air but the effect will be less dramatic.)
3. Put laboratory film over the top of the stopper.
4. Wrap the bottom half of the flask with aluminum foil. Also wrap the rubber stopper with tin foil to prevent combustion from the high oxygen level.
5. It is best to ground the aluminum foil. Using a wire with alligator clips at each end, clip one end to the foil and the other to a faucet or water pipe.
6. Touch the Tesla coil to the copper wire for about 2 minutes.
7. To generate smog, peel a twist of lemon, squeeze or rub it sharply, remove the stopper, drop in the lemon peel and replace the stopper. A whitish gas should form. Point out to your students that under atmospheric conditions, when NO_x gases are present, the smog will appear brown.

Reference:
Chan, Alan, Adele Gomez, Patricia Noel, & Ron Ulrich. 1991. Chemistry in the Environment *Woodrow Wilson National Fellowship Foundation*

SAFETY NOTE

- Goggles should be used for all laboratory work. Gloves may be recommended.
- Care should be taken to properly dispose of all chemicals used in this activity.
- Gases generated should be released with care (under a fume hood if possible).
- There is an electrical hazard due to high voltage. Keep the Tesla coil unplugged until ready for use and unplug immediately when finished.
- Keep the flask containing ozone at arm's length, and avoid breathing the gas.
- Inhaling small quantities of ozone can irritate the lungs.
- As a basis for comparison, the ozone National Ambient Air Quality Standard is 0.12 ppm (by volume) for a one-hour time period.
- To avoid the risk of an explosion- Do not add any substances to ozone other than those described here.

Background information

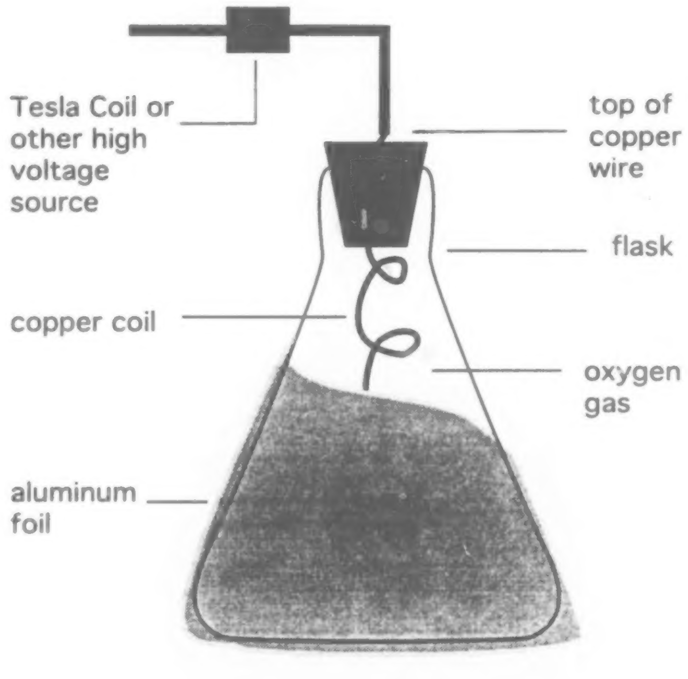
In this experiment, electrons generated by the Tesla coil at the copper coil move though the gas towards the grounded aluminum foil. However, they collide with molecular oxygen in the gas to form oxygen radicals. The oxygen radicals subsequently react with O_2 to form ozone.

The hydrocarbons in the lemon peel react with the ozone to form smog. Unsaturated hydrocarbons will produce a reaction that is about one hundred times faster than a reaction produced with saturated hydrocarbons. The unsaturated hydrocarbon in the lemon peel is limonene.

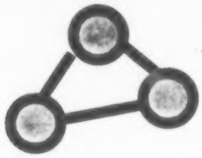
Disposal

After the demonstration, dispose of the polluting gases by filling the flask with water in a fume hood.

Setup



Graphing Ozone Levels



Name: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

- Students will graph and analyze data regarding concentrations of ground-level ozone.

MATERIALS

- Data Table
- Graph Paper and Pencil
- Computer Spreadsheet Program

Below are tables of data on the concentration of ozone in the lower atmosphere in the town of Biuone, New York. Hourly data is presented in the first table for June 11 and 12, 1992. The second table presents the maximum of each day's twenty-four readings (of hourly-averaged ozone data) for the days indicated.

Together with your partner, decide how you will graph the data given. Is this data best displayed in a bar, line, or pie graph? Why? If you select a bar or line graph, what will you put on the x-axis? What will you put on the y-axis? Give your graph a title.

Study the graphs you have made to answer the following questions:

1. What season do ozone levels tend to be the highest? On a typical day, in what part of the day do ozone levels tend to be highest?

2. What season and part of the day do ozone levels tend to be the lowest?

3. What might some factors be that contribute to increased concentrations of ozone?

4. Can you identify any other patterns by studying the graphs?

Data Tables

Hourly Average Ozone Concentrations on June 11 & 12, 1992

Date	Hour	Ozone, ppb	Date	Hour	Ozone, ppb
11-Jun	8:00 p.m.	52	12-Jun	9:00 a.m.	24
11-Jun	9:00 p.m.	42	12-Jun	10:00 a.m.	40
11-Jun	10:00 p.m.	34	12-Jun	11:00 a.m.	46
11-Jun	11:00 p.m.	35	12-Jun	12:00 noon	55
11-Jun	12:00 a.m.	38	12-Jun	1:00 p.m.	66
12-Jun	1:00 a.m.	36	12-Jun	2:00 p.m.	74
12-Jun	2:00 a.m.	24	12-Jun	3:00 p.m.	82
12-Jun	3:00 a.m.	19	12-Jun	4:00 p.m.	82
12-Jun	4:00 a.m.	9	12-Jun	5:00 p.m.	81
12-Jun	5:00 a.m.	4	12-Jun	6:00 p.m.	73
12-Jun	6:00 a.m.	7	12-Jun	7:00 p.m.	63
12-Jun	7:00 a.m.	9	12-Jun	8:00 p.m.	54
12-Jun	8:00 a.m.	12	---	---	---

1991 Maximum Daily Concentrations (Hourly Averages) of Surface Level Ozone

Date	Ozone, ppb	Date	Ozone, ppb	Date	Ozone, ppb
06-Jan.	5	06-May	47	03-Sept.	75
14-Jan.	16	14-May	67	11-Sept.	106
22-Jan.	29	22-May	84	19-Sept.	30
30-Jan.	12	30-May	122	27-Sept.	41
07-Feb.	22	07-June	59	05-Oct.	38
15-Feb.	28	15-June	106	13-Oct.	58
23-Feb.	39	23-June	44	21-Oct.	36
03-Mar.	22	01-July	63	29-Oct.	32
11-Mar.	36	09-July	61	06-Nov.	24
19-Mar.	43	17-July	122	14-Nov.	19
27-Mar.	22	25-July	60	22-Nov.	23
04-Apr.	47	02-Aug.	119	30-Nov.	37
12-Apr.	45	10-Aug.	58	08-Dec.	24
20-Apr.	32	18-Aug.	105	16-Dec.	27
28-Apr.	50	26-Aug.	53	24-Dec.	6

BEST COPY AVAILABLE

Graphing Ozone Levels TEACHER BACKGROUND

OBJECTIVES

- Students will graph and analyze data regarding concentrations of ground-level ozone.

MATERIALS

- Data Table
- Graph Paper and Pencil
- Computer Spreadsheet Program

SCIENCE SKILLS

- Data Analysis

Answers to student questions:

1. What season do ozone levels tend to be the highest? On a typical day, in what part of the day do ozone levels tend to be highest?

Ozone levels tend to be the highest in the summertime and in the late afternoon.

2. What season and part of the day do ozone levels tend to be the lowest?

Ozone levels tend to be the lowest in the wintertime and at night.

3. What might some factors be that contribute to increased concentrations of ozone?

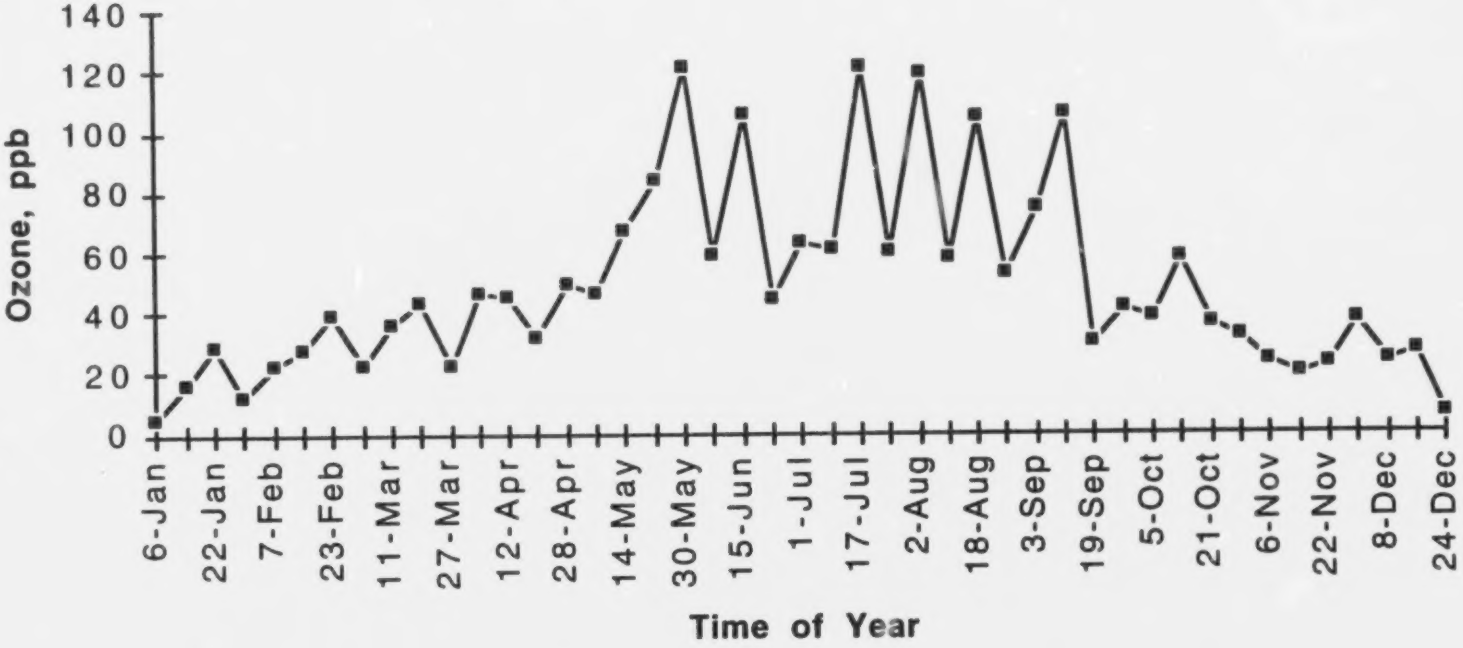
Sunlight, warm poorly mixed air, and automobile exhaust contribute to increased concentrations of ozone.

4. Can you identify any other patterns by studying the graphs?

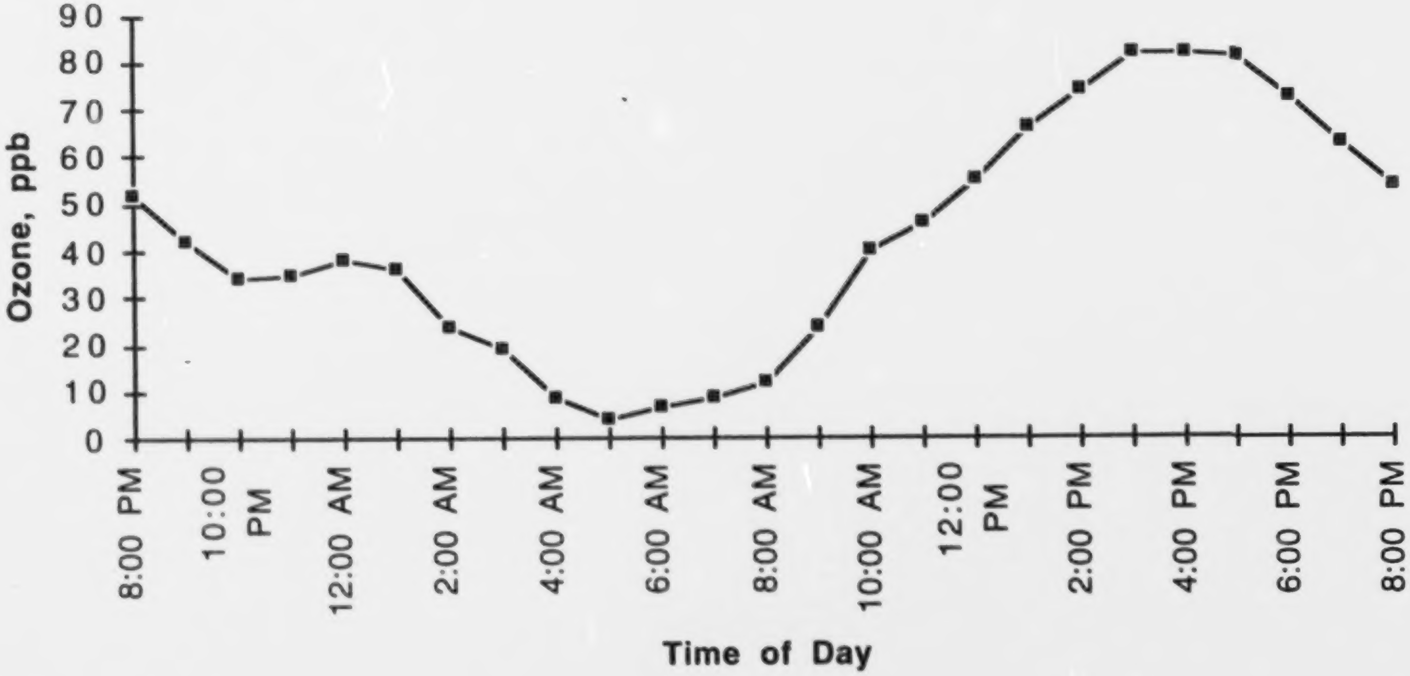
There is a strong zig-zag pattern in the annual graph, which indicates that fluctuating weather patterns greatly influence maximum daily ozone concentration levels.

On the graph showing the average hourly ozone concentrations over a 24 hour period, concentrations gradually increase until hitting a peak at about 3:00-5:00 p.m. This peak reflects the time of day on June 12, 1992 in Biuone, New York when the combination of the influence of sunlight and car traffic on ozone concentrations was maximized.

1991 Maximum Daily Concentrations (Hourly Averages) of Surface Level Ozone



Hourly Ozone Concentrations on June 11 & 12, 1992



Generic Graphing Instructions For Claris Works

Start up **Claris Works** (click on the Claris Works icon)
Choose **Spread Sheet**
Copy your data table to the spreadsheet
High light your data
Under the **Options** menu choose **Make Chart**.

Do Not Click Okay until you have gone through every category!

Click on **Gallery**
    Click on the type of graph you would like
Click on **Axis**
    Label your Y axis according to the data found in column B
    Click on X axis
    Label your X axis according to the data found in column A
Series
Click on **Labels**
    Type your title
    Unclick the X next to legend to get rid of the legend.
Click on **General**
    Click on Columns
    Click on First Column

Now click Okay

Save Your Graph!!!!!
    Under the File menu choose Save
    Type a name for your document
    Click **Save**

Use the following to customize your graph:

Any of your original choices can be changed by following the steps above. For additional formatting refer to the instructions below.

Does your X axis need to be longer than your Y axis? If so...
- Under the File menu choose Page Setup
- Click on the picture of the sideways person

Double click on your graph to bring up the chart options screen.

To switch the positions of the X and Y axes
- Click on **Gallery**
- Click in the **box** to the left of the word Horizontal.

To change the ranges of your axes
- Click on **Axis**
- Click on the axis you would like to change
- Enter a minimum value
- Enter a maximum value
- Enter a step size (This will determine how the axis labels are broken down. For example, you could have a mark every 10 units or every 20 units.)

To label your data
- Click on **Series**
- Click on the **box** to the left of Label Data

To change the placement of your legend or title
- Click on **Labels**
- If you want a horizontal legend
  - Click on the **box** next to the word Horizontal
  - Click on the diagram to the right to change the placement of your title (top) or your legend (bottom)

Before printing

Under the **View** menu choose **Show Tools**

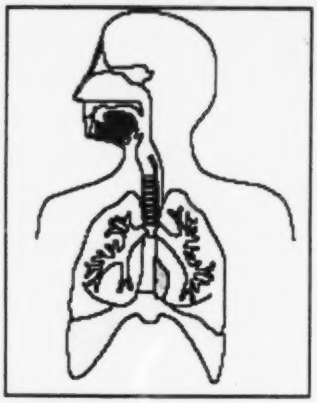
- Change all colors to pastels (except line graphs)
  - Click on the color box in the legend you want to change (A white circle will appear in the box.)
  - In the tools box (over to the left) click and hold on the upper most rainbow box
  - Drag to the Pastel color of your choice
  - **Repeat** for every series in your legend
- If you have labeled your data
  - Under the **Format** menu click and hold **Text Color**
  - Drag to **black**
- Correctly place your graph on the page
  - Get rid of cells and cell labels
    - Click on a cell in your spreadsheet
    - Under the **Options** menu choose **Display**
    - Click on all of the X's so that there aren't any left
    - Click **Okay**
  - Resize the graph
    - Under the **View** menu choose **Page View**
    - Click inside your graph and drag it so that the graph's upper left hand corner is in the same place as the page border's upper left hand corner
    - Click on the box at the lower right hand corner of your graph and drag it so it is in the same place as the page border's lower right hand corner
    - **Remember**- you can continue to move it around until you let go of the mouse button!
  - Add your name
    - In the tools box (over to the left) click on the A tool
    - Click on an appropriate place on your graph
    - Type your name
    - Click anywhere on your finished graph

Save your graph again!

Under the **File** menu choose **Print**

- Click **Print**

Ozone And Smog



Ozone is known to cause coughing, wheezing, and lung irritation.

Compounds found in smog, such as peroxyacyl nitrates (PAN's) and aldehydes, are known eye irritants.

Ozone

Ozone, O_3, is a gaseous pollutant when formed in the lower atmosphere. Reactions involving nitrogen dioxide, sunlight, and oxygen result in the formation of ozone in the troposphere. The ozone formed here is the **same compound**, but causes **different concerns** than the naturally occurring ozone that exists in the upper atmosphere.

In the lower atmosphere ozone acts as a pollutant. In the upper atmosphere, however, ozone shields the earth from damaging ultraviolet radiation. Ozone in the upper atmosphere is essential to life on earth.

Ground-level ozone can harm plants, trees, and crops; it is also a major ingredient of smog. Ozone can deteriorate and reduce the strength of products made of rubber and certain fabrics. Ozone can lead to eye irritation, breathing problems and lung damage. This pollutant is known to cause coughing, wheezing, and lung irritation at concentrations as low as 0.08 ppm over an 8-hour period. Ozone can be a special concern to children, the elderly, those who exercise outdoors, and those who suffer from asthma.

Smog

The word smog is a blend - taken from the words **smoke** and **fog**. Smog is typically thought of as a form of pollution, often a brownish haze, sometimes with an odor, that is usually found in large cities.

Smog is a general term that does not refer to one single pollutant. Instead, smog refers to a condition of deteriorated air quality. Often weather and geographical factors such as mountains and valleys contribute to the problem by "trapping" pollutants and preventing their movement, diffusion, or dispersal. Los Angeles (with its nearby surrounding mountains) is known as a city that frequently has a smog problem.

Smog is sometimes called photochemical smog or photochemical air pollution. Smog forms when oxides of nitrogen (such as NO and NO_2) react with nitrogen and oxygen in sunlight and when volatile organic compounds (VOC's) react with the nitrogen oxides in the sun.

Humans feel the effects of smog most often by experiencing respiratory trouble. While the exact degree of health effects of smog is unknown, lung function and breathing can be affected. Compounds found in smog, such as peroxyacyl nitrates (PANs) and aldehydes, are known eye irritants. Smog is also hazardous because it decreases visibility.

Photochemical Smog

Name: ______________________________

Date: ______________________________

Period: ______________________________

OBJECTIVES

- Identify and describe chemical reactions leading to the formation of ground-level ozone and photochemical smog.

NOTE: These notes are to be filled in as your teacher gives a lecture on "Photochemical Smog."

The unpolluted atmosphere is mainly composed of two elements:

____________________ and ____________________.

THEN CAME THE AUTOMOBILE ....

The type of reaction that occurs in an automobile engine is a

____________________ reaction.

In the car engine there are conditions of:

____________________ and ____________________.

These conditions lead to the thermal NO_x reaction. Write this reaction:

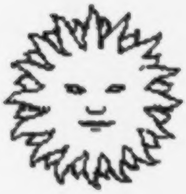
____.

The product of the thermal NO_x reaction is nitrogen monoxide,
__________ . (Write the formula for nitrogen monoxide)

Nitrogen monoxide is generated by the above chemistry in combustion processes such as automobiles and power plants. It can subsequently react with oxygen in air to form nitrogen dioxide. This is a reddish-brown gas which is visible to the human eye at high concentrations (above about 1 ppm). The reaction for the oxidation of nitrogen monoxide to nitrogen dioxide by oxygen is:

____

(Make sure the reaction is balanced.)



The product of this reaction can then be decomposed by light of about 390 nanometers wavelength to form these products:

NO_2 + sunlight -> _____ + _____ .

Unstable molecules react easily, while unstable molecules do not react easily. Which of these products is very reactive and unstable?

____

Write the equation for the formation of ozone:

____

What does M* refer to in the equation you just wrote?

105

What role does the M* play?

Describe the formation of photochemical smog from ozone.

____

Some examples of where volatile organic compounds (VOC's) come from are:

________________________, ________________________,

______________________, or ______________________.

Time Of Day	Factors Affecting Ozone Levels	Relative Level of Ozone in Atmosphere
Morning		
Afternoon		
Evening		
Night		

Let's look at a simplified scenario of ozone formation on a typical summer sunny day. Fill in chart above.

The effects of smog cause irritation to which body system: (Circle one.)
muscular respiratory skeletal nervous circulatory

List 4 symptoms of exposure to high ozone concentration:

____________________ ____________________

____________________ ____________________

Formation Of Smog TEACHER BACKGROUND

OBJECTIVES

- Students will identify and describe chemical reactions leading to the formation of ground-level ozone and photochemical smog.

Answers

The unpolluted atmosphere is mainly composed of two elements.

nitrogen and oxygen

THEN CAME THE AUTOMOBILE ....

The type of reaction that occurs in an automobile engine is a

combustion reaction.

In the car engine there are conditions of:

high temperature and high pressure

These conditions lead to the thermal NO_x reaction. Write this reaction:

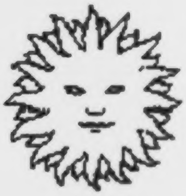
$N_2 + O_2 \rightarrow 2NO$.

The product of the thermal NO_x reaction is nitrogen monoxide, NO . (Write the formula for nitrogen monoxide)

Nitrogen monoxide is generated by the above chemistry in combustion processes such as automobiles and power plants. It can subsequently react with oxygen in air to form nitrogen dioxide. This is a reddish-brown gas which is visible to the human eye at high concentrations (above about 1 ppm). The reaction for the oxidation of nitrogen monoxide to nitrogen dioxide by oxygen is:

$\underline{\quad 2NO + O_2 \rightarrow 2NO_2 \quad\quad}$.

(Make sure the reaction is balanced.)



The product of this reaction can then be decomposed by light of about 390 nanometers wavelength to form these products:

NO_2 + sunlight -> $\underline{\ NO\ }$ + $\underline{\ O\ }$.

Unstable molecules react easily, while unstable molecules do not react easily. Which of these products is very reactive and unstable?
$\underline{\quad O \quad}$

Write the equation for the formation of ozone:

$\underline{\quad O + O_2 + M^* \rightarrow O_3 + M^* \quad\quad}$.

What does M^* refer to in the equation you just wrote?

The M^* represents another molecule.

What role does the M^* play?

It absorbs excess energy.

Once ozone is formed, it can react to form photochemical smog:

$NO_x + O_3$ + VOC + light —> photochemical smog + peroxyacetyl nitrate (PAN)

Some examples of where volatile organic compounds (VOC's) come from are: **escaped gasoline vapor,** **unburned or partially burned fuel,** **dry cleaners,** or **printers.**

Time of Day	Factors Affecting Ozone Levels	Relative Level of Ozone in Atmosphere
Morning	The sun rises. NO_x and hydrocarbon emissions come from automobile exhaust during morning rush hour.	medium-low
Afternoon	The intensity of sunlight increases. More emissions as people drive home from work.	high
Evening	The intensity of the sun decreases.	medium
Night	The sun sets. Car traffic subsides.	low

Let's look at a simplified scenario of ozone formation on a typical summer sunny day. Fill in the chart above.

The effects of smog cause irritation to which body system:

muscular **RESPIRATORY** skeletal nervous circulatory

List 4 symptoms of exposure to high ozone concentration:

coughing

shortness of breath

headache

eye, nose, throat irritation

Solutions

THINK ABOUT IT

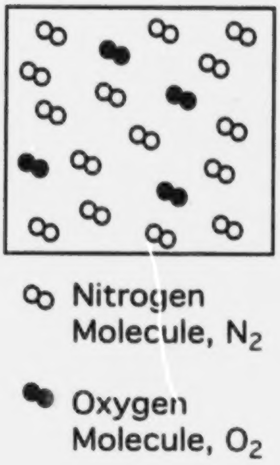
If you wanted to make up a solution of acid rain,

____

would be a solvent and

____

would be the solute.



What's in a Solution?

If you've ever had a cup of hot tea, you were drinking a solution. The water in a swimming pool or in the ocean is a solution. A mixture is a solution if its components cannot be separated by filtration, and will not settle out.

Solutions are not always in the liquid phase. The atmosphere is a solution. The gas given to surgery patients to make them unconscious is a solution. When you recognize the fragrance of a perfume or the odor of a food you like, you are smelling a gaseous solution. Even a solid material, like brass, can be considered a solution.

Types of solutions

Whenever one substance is dissolved into another, we call the substance that is dissolved the solute, and the substance into which it is dissolved the solvent. In a glass of sugar water, sugar is the solute, and water is the solvent.

Liquid solutions are the most familiar. Liquid solutions can be made of a solid dissolved in a liquid, or two liquids mixed together, or a gas dissolved in a liquid. For liquid solutions, water is commonly the solvent. These are called aqueous solutions.

Sugar water is one example of how solids can be dissolved in liquids to form a solution. A salt water solution is another example. In that case, salt is the solute, and water is the solvent.

Liquids can be mixed together to form solutions. An example of a solution with a liquid solute in a liquid solvent is alcohol and water mixed together.

Gases can also dissolve into a liquid to form a solution. We could take the sugar water and dissolve carbonic acid gas into it to make soda. Here, water is the solvent and carbonic acid is the solute. When sulfuric acid gas dissolves in rainwater, we call the solution formed acid rain.

Solutions can be mixtures of gases. You have learned that the atmosphere is composed of a mixture of gases, 78 percent of which is nitrogen. The molecules of other gases, such as oxygen and carbon dioxide, mingle freely with the nitrogen. In the atmosphere, nitrogen and oxygen molecules are uniformly distributed, as shown to the left.

THINK ABOUT IT

Classify the following substances as solutions or suspensions.

- muddy water
- a cup of tea
- calamine lotion
- oil-based paint
- salt water
- soda pop
- orange juice
- gravy
- Italian salad dressing
- household ammonia
- vinegar
- milk of magnesia

A **solution** is a uniform, or homogenous mixture. Not all mixtures are homogeneous. Smoke consists of suspended particles in the air and can be called a **suspension**. Small particles stick together to form larger, visible particles. Unlike individual molecules of a solution, these suspended particles are sometimes large enough to be seen and are not evenly distributed.

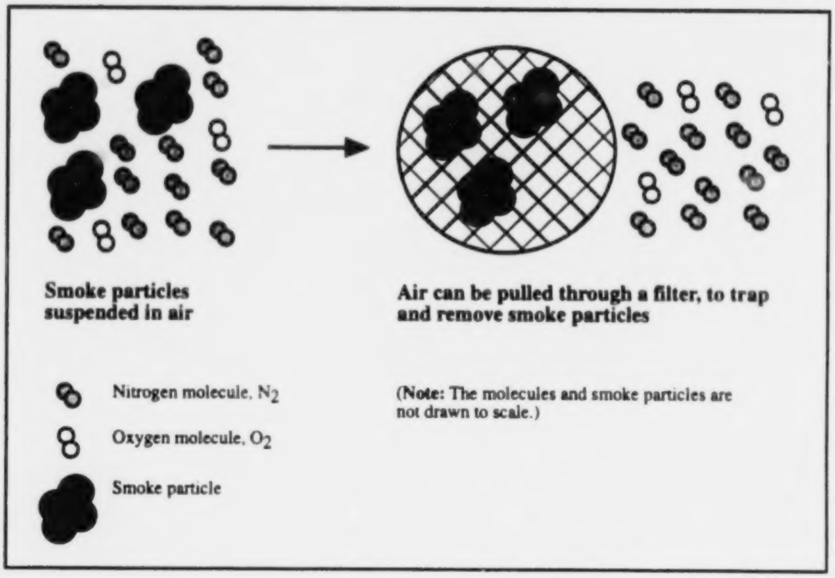
Smog is another example of a suspension. Suspensions are often cloudy or opaque in appearance. The particles in a suspension often can settle out or be filtered out. The components of a solution, by contrast, cannot be separated by filtration, and will not settle out.

Smoke and smog are suspensions, and they are also forms of air pollution.

Concentration of solutions

Apple juice concentrate is a solution. When purchased, it has a relatively large amount of solute (apple juice) because a great deal of the solvent (water) has been removed. When consumers take the apple juice concentrate home, they dilute the contents with water before drinking it.

In chemistry, the concentration of a solution is expressed in terms of how much solute exists in a given amount of solution. A **concentrated** solution contains a relatively large amount of solute. In contrast, a solution that contains a relatively small amount of solute is called **dilute**.



Smoke particles suspended in air

Air can be pulled through a filter, to trap and remove smoke particles

(**Note:** The molecules and smoke particles are not drawn to scale.)

EXAMPLE

Question:

A solution is 12 percent ammonia by volume. Express this concentration in parts per hundred, pph.

Answer:

12 % is the same as 12 pph, so the concentration is 12 pph.

Cola syrup from a soda machine is another example of a concentrated solution. When soda water is added, the solution is diluted. The terms "concentrated" and "dilute", however, are not exact expressions. There are several ways of measuring the concentration of solutions so that their exact level of concentration is known. One way of measuring concentrations of solutions is to refer to the **percent** concentration.

Solutions related to atmospheric chemistry are often dilute solutions. The amount of ozone in the atmosphere compared to other gases, for example, is small. Dilute solutions are often measured in terms of **parts per million**.

Relationships between percents (by mass or volume) and parts per million will be discussed below.

Concentrations as a Percent by Volume

Sometimes concentrations are expressed as percent by volume. The volume of the solute can be divided by the total volume of the solution to determine the percent concentration of the solution. For example, rubbing alcohol in the medicine cabinet may be a 5% solution of alcohol. This means that if there are 100 milliliters of solution in the bottle, 5 milliliters are pure alcohol. The remaining 95 milliliters are pure water. Five milliliters of pure alcohol (the solute) divided by 100 milliliters of solution equals a 5% solution of rubbing alcohol.

Another way of expressing percent is "parts per hundred" So we can say that the bottle of rubbing alcohol is a 5% solution, or it is a 5 parts per hundred solution of rubbing alcohol.

PROBLEM SET

1. The atmosphere consists of 78% nitrogen, 21% oxygen, and 1% other gases. What is the composition of the atmosphere in terms of parts per hundred?

2. What is the concentration in parts per hundred of a brand of syrup that contains 7% pure maple syrup?

3. A soda is 21 parts per hundred sugar. What is the percent concentration of sugar in the soda?

Concentrations as Parts Per Million

Percent by volume or parts per hundred are commonly used to express concentrations, but for very dilute solutions, discussing concentration in terms of parts per million (ppm) is more appropriate. (Using ppm yields numbers that are easier to work with.)

What does "parts per million" mean? If three liters of chlorine are added to a swimming pool that already has 999,997 liters of water in it, then the swimming pool is filled with a solution that is 3 parts per million chlorine.

Extremely dilute solutions can be discussed in terms of parts per billion (ppb), or even parts per trillion (ppt).

Refer to Figure 1 for a chart of the federally regulated standards for exposure to some air pollutants in parts per million. An air pollution standard is a concentration of a pollutant set by the U.S. Environmental Protection Agency that should not be exceeded. If too many exceedances occur in a given area, increased government regulations and/or sanctions may be applied. The 8-hour average standard for carbon monoxide (CO) means that no one should legally be exposed to a concentration of CO that averages more than 9 parts per million over an 8 hour period. Similarly, no one should be exposed to a concentration of CO that averages more than 35 ppm over a one hour period.

Refer to the chart of pollutant standards, and convert the figures from parts per million to parts per billion. Then convert them to parts per hundred. The first example is done for you.

EXAMPLE:

One billion is the same as 1,000 times one million, so:
9 ppm CO = 9,000 ppb CO

Similarly, one hundred is $\frac{1}{10,000}$ or .0001 of one million, so:
9 ppm CO=.0009 pph CO

PROBLEM SET

Repeat the calculations as above for:

1. 35 ppm CO
2. .053 ppm NO_2
3. 0.12 ppm O_3.

Pollutant	Standard
CO (Carbon Monoxide) 8-hour Average 1-hour Average	 9 ppm 35 ppm
NO_2 (Nitrogen Dioxide) Annual Arithmetic Mean	 0.053 ppm
O_3 (Ozone) 1-hour Average	 0.12 ppm

Solutions

Answer Key to Solutions Problem Sets

Think about It:

If you wanted to make up a solution of acid rain, **rainwater** would be a solvent and **sulfuric acid** would be the solute.

Think about It

Classify the following substances as solutions or suspensions.

muddy water **(sus)**
a cup of tea **(sol)**
calamine lotion **(sus)**
oil-based paint **(sus)**
salt water **(sol)**
soda pop **(sol)**
orange juice **(sus)**
gravy **(sus)**
Italian salad dressing **(sus)**
household ammonia **(sol)**
vinegar **(sol)**
milk of magnesia **(sus)**

(continued on next page)

Problem Set:

1. The atmosphere consists of 78% nitrogen, 21% oxygen, and 1% other gases. What is the composition of the atmosphere in terms of parts per hundred?

   78 parts per hundred nitrogen

   21 parts per hundred oxygen

   1 part per hundred other gases

2. What is the concentration in parts per hundred of a brand of syrup that contains 7% pure maple syrup?

   7 parts per hundred maple syrup

3. A soda is 21 parts per hundred sugar. What is the percent concentration of sugar in the soda?

   The soda is 21% sugar.

Problem Set:

Repeat the calculations as above for:

1. 35 ppm CO **= 35,000 ppb CO** **=.000012 pph O_3**
2. .053 ppm NO_2 **= 53 ppb NO_2** **= .0000053 pph NO_2**
3. 0.12 ppm O_3 **=120 ppm O_3** **=.0035 pph CO**

Out Of Sight, Out Of Mind

Name: ____________________

Date: ____________________

Period: ____________________

OBJECTIVES

- Investigate the process of serial dilution.
- Develop operational definitions of ppt and ppm.
- Discover that color recognition is dependent on concentration.
- Design an experiment.
- Observe qualitatively and quantitatively.
- Modify experimental designs based on experience.
- Interpret results.

MATERIALS

Chemicals

10% food coloring solution
water

Materials

24-well plate
10 toothpicks
10 disposable pipets

Introduction

Concentration is used to measure the amount of most pollutants in the air, water, and soil. The Environmental Protection Agency sets standards that represent currently acceptable concentration levels for pollutants in the environment. When the concentration of a pollutant is so low that its presence in the environment cannot be detected, should we conclude that it is no longer a pollutant?

This investigation will allow you to examine different levels of concentration by using food coloring in various concentrations. The use of food coloring will allow you to see the effects of different dilutions and make visual comparisons of different concentrations. Although food coloring is not a pollutant, in this experiment, food coloring will simulate pollutants found in the environment.

The starting concentration will be a 10 percent solution of food coloring in water. This means that if you had 100 grams of this solution, you would have 10 grams of food coloring and 90 grams of water. You could also describe this solution as 10 parts of dye to every 100 parts of solution. (Notice that would be 10 grams of dye to 100 grams of solution, not 10 grams of dye to 100 grams of water.)

Many pollutants are reported not at a "parts per ten" or "parts per hundred" level, but at a "parts per thousand" or "parts per million" level. Your task is to design an experimental procedure to prepare a one part per thousand and a one part per million solution, using the materials listed below. Remember that

$$1\text{ ppm} = \frac{1\text{ part solute}}{1{,}000{,}000\text{ parts solution}}$$

Make a **Data Table** for recording the concentration and careful observations of the color for every solution you make in each step of the procedure.

Your **lab report** should include the following

A. Describe the PURPOSE of the experiment- What was your task?

B. Under the heading PROCEDURE, outline the steps you carried out.

C. Display a copy of your DATA TABLE and observations.

D. Report on the RESULTS. Evaluate the results of your procedure, explain how your conclusions are based on your observations, and use your results to comment on the question posed in the first paragraph:

"When the concentration of a pollutant is so low that its presence in the environment can no longer be detected, should we conclude that it is no longer a pollutant?"

Questions to get you started

1. A 10% solution is the same as how many parts per hundred? This concentration is the same as how many parts per ten?

2. In this lab, what is the solute? What is the solvent? What does the solution consist of?

3. Draw a model of one drop of 10% solution of food coloring. How many equal parts should you divide the drop into? How many parts should you color in to represent the amount of pure food coloring present in the drop?

4. Try combining any number of drops of solute and solvent in the first well. Draw models of your drops as in question **# 3** Express the new concentration of the solution you have created in parts per _____. Check with your teacher to see if you have expressed the concentration correctly.

5. Now what?

More questions to concentrate on

1. How many wells did you use to get a 1 part per million concentration of food coloring in water? To how many wells would you need to extend this experiment to get a one part per billion concentration? How about a one part per trillion concentration?

2. One gallon of chlorine in the Heman Park swimming pool is the same as one part per million. One pinch of salt on 10 tons of potato chips would be the equivalent of 1 part per billion. So would one inch out of a 16,000 mile journey, which is approximately the same as chartering a direct round trip flight from St. Louis, MO to Calcutta, India. One part per trillion is approximately equal to a six inch step on the way to the sun. Invent your own comparative example of parts per million, billion or trillion.

Out Of Sight Out Of Mind

TEACHER BACKGROUND

OBJECTIVES

Students will:

- Investigate the process of serial dilution.
- Develop operational definitions of ppt and ppm.
- Discover that color recognition is dependent on concentration.
- Design an experiment.
- Observe qualitatively and quantitatively.
- Modify experimental designs based on experience.
- Interpret results.

MATERIALS

Chemicals
10% food coloring solution
water

Materials
24-well plate
10 toothpicks
10 disposable pipets

SCIENCE SKILLS

- Laboratory Procedures

Students spend one day in the lab designing a procedure and data table, and carrying out the experiment. Students turn in a lab report that includes a write-up of the procedure.

Notes and expected outcomes

Most students will develop a plan in which they use consistent drop size and serial dilution to prepare the desired solutions. Their procedures should clearly identify the number of drops of 10% food coloring solution and water used. If one drop of 10% solution in mixed with 9 drops of water, then a "one part per hundred" solution will be prepared. Taking one drop of that solution, after careful mixing, and dilution with 9 drops of water will create a "one part per thousand" mixture, and so on. The color will be detected by students at different levels, but certainly no color can be detected by the eye at the "one part per million" level. This does not mean that no food coloring is present, it just means the level is too low to be detected visually.

Suggested scoring check sheet

(Expected Maximum of 15 points; 5 points of Extra Credit)

The procedure is appropriate and complete. **(5 points maximum)**

Observations and data are well-organized and easily understood. **(5 points maximum)**

Conclusions are drawn and are based on available evidence. **(5 points maximum)**

Extra credit work is present, such as a good discussion of the limits of detection, redesigning the experiment for the future, and/or sophisticated error analysis. **(+5 points maximum)**

Article Analysis

The following Associated Press news story appeared in the St. Louis Post Dispatch *on June 9, 1993.*[1]

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[1] Article reprinted with permission of the Associated Press

THINK ABOUT IT

1. The standard for ozone pollution is the maximum allowable concentration of ozone that may occur in a one hour period. What is the maximum allowable concentration for ozone?
2. How might that concentration be expressed in parts per billion?

(continued on the next page)

Pediatricians' Group Urges U.S. to Tighten Ozone Regulations

The federal standard for ozone pollution is too lax to protect children, the nation's largest group of pediatricians said Tuesday.

"Levels of ozone which are commonly found on summer afternoons can be dangerous to exercising children," said Dr. Ruth A. Etzel, a member of the Committee on Environmental Health of the American Academy of Pediatrics.

Ozone inflames lung tissue, hampering breathing. It is the chief ingredient in smog, which forms in the lower atmosphere when sunlight reacts with gasoline vapor and chemicals formed in the burning of fossil fuels, such as coal.

The 45,000-member academy, in its first policy statement on outdoor air pollution, said the federal government should consider toughening its ozone standard of 0.12 parts per million of air.

The academy did not recommend a new standard. Dr. J. Routt Reigart, head of the academy's environment committee, said that is best left to regulators who must weigh economic concerns.

The academy's committee reviewed 47 major studies through 1991, said Etzel, chief of the Air Pollution and Respiratory Health Branch of the Centers for Disease Control and Prevention in Atlanta.

Levels of ozone which are commonly found on summer afternoons can be dnagerous to children.

3. The information in the exercise "Graphing Ozone Data" (see pg. 103) is taken from actual records of ozone concentrations in Buione, N.Y. This data is representative, however, of trends found in most counties of the United States. Do the ozone levels in Buione ever exceed federal standards? If not, how close does the highest reading come to approaching the standard? If so, when is the standard exceeded?

4. Do you agree with the pediatricians' recommendation in the preceding article? Why or why not? What further information would help you in making this decision?

The academy's recommendation, along with suggestions for better pollution prevention and medical advice for children, is published in the June issue of the journal of Pediatrics, released Tuesday.

Lung inflammation occurs in anyone exposed to ozone, but asthmatics—one in 20 youngsters—may have their lung problems worsened for life by exposure to substances that trigger attacks, Reigart said in a telephone interview.

"There's been this enormous upsurge of asthma and asthma-related deaths in this country, and ozone is one of the reasons," said Reigart, an associate professor of pediatrics at the Medical University of South Carolina in Charleston.

The Environmental Protection Agency, which sets air-pollution standards for the federal government, in March refused to tighten the rules on ozone, despite a suit filed by health groups.

In order to meet a deadline set by a U.S. District Court in New York to update air-quality standards, the EPA reissued the standard it set in 1978, saying studies through 1989 did not warrant a change.

The agency promised to review recent research, acknowledging that some of it suggests tougher standards may be warranted.

It is not known when the review will be done, said the EPA's John H. Haines, who is in charge of developing new standards.

St. Louis Ozone Task Force

Name: ______________________

Date: ______________________

Period: ______________________

OBJECTIVES

Students will

- Analyze ozone pollution data
- Create a solution for the problem of ozone pollution
- Effectively communicate results

MATERIALS

- Raw data on ozone pollution for one year, one set per team or individual
- Access to computers, if possible
- Instruction sheets

An **ozone community task force** has been assembled to attempt to reduce ozone pollution in the St. Louis area. St. Louis has exceeded the current standard of .12 ppm ozone concentration several times each summer. If the number of days that the concentration of ozone is exceeded in St. Louis is not lowered by November, 1996, St. Louis's non-attainment status may be revised from "moderate" to "serious". Significant government regulation and/or withdrawal of government funds could follow.

Your team is made up of the following professions representing the community:

1. City Planner, Politician, or Corporate CEO.
2. Engineer, Inventor, Research Scientist, or Architect
3. Educator, Writer, or Journalist

Your task is to answer the questions below, determine when ozone pollution is a problem and why, and develop a suggested solution to the problem, based on the data at hand as well as the expertise your profession has to offer. Your task force will report the results to City Hall in group and individual written depositions.

1. Each member of the team should select which profession they would like to represent, now. Each team member must represent a different profession.

2. Give your task force a name.

3. The following steps are to be completed as a group. You may divide up the work in any way you choose, or work on it all together. Your group will receive a score for time spent on task during meeting time as observed by the Mayor. This score will count towards 33% of the overall score your group receives in its report. Any work not completed in class must be done after school. No extensions will be given.

A. Determine from the data available the time of day and year when ozone levels tend to be the highest in St. Louis. Support your answers with a chart or graph.

B. The current standard for ozone is .12 ppm over a one hour period. A standard is a level of pollution set by the EPA which should not be exceeded. If the level exceeds .12 ppm over a one hour period three or more times per year, then St. Louis is in violation of the standard.

Health studies have shown that ozone levels can adversely affect health, especially in children, at levels as low as .08 ppm over a six hour period. As a result of these studies, the EPA standard may change from .12 ppm over a one hour period to .08 ppm over a six hour period. What kind of impact might this change have in St. Louis on the number of exceedances of the ozone standard per year? Will the number of exceedances increase, decrease, or stay the same? Support your answer with a chart or graph.

C. Use information from the Ozone Scavenger Hunt, the data you have collected, and what you have learned previously to discuss factors that may contribute to the ozone pollution problem in St. Louis.

D. Develop a task force report. Include in the report your responses to A, B, and C above. All members of the team will receive the same score from city hall for the task force report.

4. The following assignment is to be completed individually. Make a suggestion for how ozone pollution levels can be reduced in St. Louis, based on the studies of your task force, and the expertise your profession has to offer. Inventors invent things, educators educate, politicians pass legislation, city planners design how cities function, etc. Recommendations will receive individual scores from City Hall. Your report should include the following:

A. List your name, your task force name, and the name of your profession.

B. From the point of view of a representative of your profession, should the ozone standard be changed? Why or why not?

C. Explain your proposal to reduce ozone levels in St. Louis that utilizes the expertise of your profession.

St. Louis Task Force TEACHER BACKGROUND

OBJECTIVES

Students will

- Analyze ozone pollution data
- Create a solution for the problem of ozone pollution
- Effectively communicate results

MATERIALS

- Raw data on ozone pollution for one year, one set per team or individual
- Access to computers, if possible
- Instruction sheets

SCIENCE SKILLS

- Data Analysis
- Problem Solving
- Communicating Results

Notes and Expected Outcomes

This activity is based on St. Louis data. To revise this activity to apply to your local area, use the form letter at the end of these teacher pages to ask the USEPA for data on ozone levels where you live.

Cooperative Learning

This activity contains the essential components of a cooperative learning exercise, as outlined below.

Positive Interdependence

Students prepare and submit one written analysis of the ozone problem per group. A single grade is given for the group report. Other possibilities include providing one computer per group, or giving each individual in the group different data subsets.

Individual Accountability

Each of the three students must come up with a plan to reduce emissions, each from a different point of view:

1. City Planner, Politician, or Corporate CEO.
2. Engineer, Inventor, Research Scientist or Architect
3. Educator, Writer, or Journalist

Students write individual reports, for which they receive individual grades.

Criteria for Success

Clearly identify the criteria for success for the lesson and communicate it to students. The materials state that "*Your task is to answer the questions below, determine the main factors contributing to ozone pollution, and develop a suggested solution to the problem, based on the data at hand as well the expertise your profession has to offer. Your task force will report the results to City Hall in group and individual written depositions.*"

BEST COPY AVAILABLE

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DATE: 11/03/95                    EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)                           PAGE     13
AMP350                                          AIR QUALITY SUBSYSTEM
                                              RAW DATA REPORT  1-HOUR LISTING
            (44201) OZONE                                                                 CAS NUMBER: 10028156
                                                 STATE (29): MISSOURI
                                                      APR 1994

SITE-ID: 29-189-0006    POC: 1                  AQCR (070): METROPOLITAN ST. LOUIS                 LATITUDE:  38:36:49 N
COUNTY (189):    ST LOUIS CO                    URBAN-AREA (0000):NOT IN AN URBAN AREA             LONGITUDE: 90:29:45 W
CITY (00000):    NOT IN A CITY                  LAND USE (1): RESIDENTIAL                          UTM ZONE: 15
SITE ADDRESS:    305 WEIDMAN ROAD (QUEENY)      LOCATION SETTING (3): RURAL                        UTM-NORTHING: 4276698
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO                                     UTM-EASTING:    718034
SITE COMMENTS:  ILLINOIS GRID 406 E 708 N                                                          ELEVATION-MSL:    175 M
MONITOR COMMENTS: 11                                                                               PROBE HEIGHT:       4 M
MONITOR TYPE (2): SLAMS                         MINIMUM DETECTABLE:        .005                    INTERVAL: 1
UNITS (007): PPM                                REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

DAY/HOUR
     0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 OBS MAX
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 1   .000 .000 .002 .020 .025 .023 .017 .026 .044 .047 .052 .058 .065 .067 .067 .066 .066 .065 .059 .038 .035 .038 .050 .052 24 .067
 2   .050 .048 .036 .034 .037 .045 .040 .035 .051 .048 .051 .053 .056 .055 .049 .040 .030 .026 .037 .034 .034 .036 .030 .028 24 .056
 3   .028 .032 .032 .031 .029 .027 .028 .028 .032 .034 .036 .038 .043 .043 .044 .046 .048 .047 .046 .037 .011 .003 .000 .000 24 .048
 4   .000 .000 .000 .000 .000 .001 .005 .008 .022 .024 .032 .043 .044 .046 .049 .049 .047 .048 .048 .044 .041 .045 .046 .046 24 .049
 5   .045 .045 .045 .044 .043 .037 .015 .010 .013 .012 .010 .016 .017 .017 .017 .015 .016 .016 .016 .018 .018 .020 .024 .026 24 .045
 6   .029 .033 .034 .033 .031 .026 .021 .021 .025 .030 .029 .030 .033 .032 .031 .037 .039 .037 .028 .015 .014 .005 .002 .001 24 .039
 7   .001 .001 .001 .001 .001 .001 .003 .005 .011 .025 .039 .037 .039 .046 .049 .051 .037 .036 .044 .037 .035 .038 .033 .031 24 .051
 8   .031 .028 .028 .024 .020 .012 .007 .013 .022 .031 .034 .047 .053 .056 .060 .062 .062 .058 .055 .054 .057 .058 .060 .061 24 .062
 9   .060 .059 .057 .058 .057 .055 .044 .033 .044 .050 .048 .046 .049 .050 .046 .036 .037 .037 .029 .031 .025 .032 .043 .044 24 .060
10   .042 .042 .047 .048 .049 .045 .044 .044 .041 .039 .035 .034 .031 .038 .040 .027 .027 .030 .031 .030 .036 .034 .038 .040 24 .049
11   .038 .039 .037 .033 .030 .026 .020 .021 .019 .019 .021 .020 .019 .014 .008 .004 .014 .013 .007 .003 .002 .010 .017 .013 24 .039
12   .007 .003 .002 .003 .011 .008 .012 .025 .032 .040 .045 .047 .048 .049 .049 .047 .046 .046 .043 .042 .043 .043 .044 .047 24 .049
13   .048 .048 .045 .043 .042 .036 .032 .031 .030 .032 .034 .038 .042 .050 .053 .052 .052 .052 .045 .024 .002 .009 .017 .006 24 .053
14   .030 .052 .052 .049 .050 .049 .044 .029 .035 .047 .059 .062 .065 .067 .062 .061 .067 .061 .052 .047 .041 .039 .039 .039 24 .067
15   .039 .038 .037 .037 .060 .051 .037 .025 .040 .033 .035 .037 .040 .045 .046 .045 .046 .045 .044 .044 .043 .039 .032 .030 24 .060
16   .037 .037 .035 .034 .031 .034 .029 .034 .040 .043 .044 .048 .053 .056 .056 .058 .059 .058 .056 .050 .051 .045 .038 .032 24 .059
17   .042 .045 .047 .045 .040 .031 .038 .039 .046 .048 .050 .052 .055 .059 .062 .063 .059 .050 .052 .045 .031 .030 .033 .038 24 .063
18   .042 .038 .048 .060 .061 .059 .048 .060 .066 .069 .066 .066 .065 .063 .064 .064 .061 .059 .055 .054 .051 .046 .045 .049 24 .069
19   .053 .055 .054 .053 .058 .049 .037 .034 .038 .041 .041 .047 .056 .060 .063 .066 .067 .063 .055 .052 .051 .048 .042 .035 24 .067
20   .032 .038 .035 .033 .033 .021 .011 .021 .038 .048 .049 .048 .046 .046 .055 .061 .062 .059 .049 .032 .023 .022 .026 .016 24 .062
21   .012 .023 .037 .038 .026 .019 .013 .019 .022 .026 .014 .021 .030 .022 .027 .032 .030 .021 .023 .022 .021 .028 .029 .024 24 .038
22   .020 .012 .009 .010 .013 .014 .011 .019 .026 .034 .041 .048 .057 .058 .064 .066 .064 .062 .057 .043 .027 .030 .026 .025 24 .066
23   .017 .013 .003 .002 .003 .015 .009 .015 .026 .039 .052 .060 .063 .063 .066 .067 .067 .061 .056 .048 .038 .035 .034 .025 24 .067
24   .033 .046 .054 .049 .055 .056 .056 .059 .063 .066 .076 .082 .078 .077 .072 .069 .067 .065 .062 .057 .061 .067 .071 .071 24 .082
25   .069 .067 .063 .060 .058 .052 .024 .043 .047 .049 .050 .053 .053 .052 .051 .050 .052 .052 .050 .047 .046 .044 .043 .038 24 .069
26   .039 .039 .039 .040 .042 .036 .028 .028 .032 .036 .039 .042 .043 .044 .046 .046 .047 .047 .044 .039 .046 .041 .033 .042 24 .047
27   .042 .030 .033 .031 .031 .023 .019 .023 .025 .026 .027 .030 .035 .035 .032 .031 .016 .029 .025 .029 .032 .026 .020 .023 24 .042
28   .023 .025 .023 .022 .019 .015 .010 .002 .004 .016 .018 .014 .012 .013 .021 .030 .042 .043 .041 .046 .044 .038 .036 .032 24 .046
29   .030 .028 .026 .026 .028 .027 .024 .022 .019 .017 .018 .019 .020 .019 .022 .028 .025 .018 .015 .014 .015 .012 .008 .005 24 .030
30   .012 .017 .016 .016 .016 .015 .013 .011 .008 .008 .012 .012 .012 .014 .021 .023 .025 .023 .025 .025 .025 .028 .029 .032 24 .032
31

NO.    30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30   30
MAX  .069 .067 .063 .060 .061 .059 .056 .060 .066 .069 .076 .082 .078 .077 .072 .069 .067 .065 .062 .057 .061 .067 .071 .071
MEAN .032 .033 .033 .033 .033 .030 .025 .026 .032 .036 .039 .042 .044 .045 .046 .046 .046 .044 .042 .037 .033 .033 .033 .032

          MONTHLY OBSERVATIONS   720                  MONTHLY MEAN  .036                   MONTHLY MAXIMUM .082
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DATE: 11/03/95                           EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)                               PAGE     14
AMP350                                                  AIR QUALITY SUBSYSTEM
                                                    RAW DATA REPORT  1-HOUR LISTING
           (44201) OZONE                                                                              CAS NUMBER: 10028156
                                                      STATE (29): MISSOURI
                                                           MAY 1994

SITE-ID: 29-189-0006    POC: 1                       AQCR (070): METROPOLITAN ST. LOUIS                           LATITUDE:  38:36:49 N
COUNTY (189):    ST LOUIS CO                         URBAN-AREA (0000):NOT IN AN URBAN AREA                       LONGITUDE: 90:29:45 W
CITY (00000):    NOT IN A CITY                       LAND USE (1): RESIDENTIAL                                    UTM ZONE: 15
SITE ADDRESS:    305 WEIDMAN ROAD (QUEENY)           LOCATION SETTING (3): RURAL                                  UTM-NORTHING: 4276698
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO                                                    UTM-EASTING:    718034
SITE COMMENTS:   ILLINOIS GRID 406 E 708 N                                                                        ELEVATION-MSL:   175 M
MONITOR COMMENTS: 11                                                                                              PROBE HEIGHT:      4 M
MONITOR TYPE (2): SLAMS                              MINIMUM DETECTABLE:        .005                              INTERVAL: 1
UNITS (007): PPM                                     REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

DAY/HOUR
     0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 OBS MAX
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  1  .034 .035 .036 .033 .028 .027 .031 .037 .037 .037 .038 .039 .039 .041 .038 .039 .039 .031 .026 .019 .014 .015 .017 .016 24  .041
  2  .012 .009 .008 .010 .008 .009 .004 .023 .024 .038 .042 .044 .047 .048 .044 .043 .044 .042 .039 .037 .030 .028 .020 .017 24  .048
  3  .019 .021 .018 .020 .029 .027 .015 .019 .028 .033 .035 .041 .041 .046 .050 .053 .050 .052 .048 .040 .029 .033 .028 .017 24  .053
  4  .009 .004 .008 .005 .003 .004 .004 .007 .016 .018 .026 .040 .052 .053 .052 .061 .060 .057 .054 .041 .024 .014 .005 .001 24  .061
  5  .001 .001 .001 .001 .002 .003 .006 .018 .041 .051 .056 .062 .066 .069 .068 .066 .065 .064 .061 .042 .019 .019 .014 .007 24  .069
  6  .012 .015 .018 .025 .019 .011 .005 .002 .002 .003 .005 .007 .017 .022 .020 .015 .020 .017 .013 .013 .013 .010 .013 .014 24  .025
  7  .020 .019 .012 .008 .013 .012 .011 .017 .026 .021 .027 .032 .040 .043 .044 .049 .047 .046 .043 .041 .032 .023 .015 .011 24  .049
  8  .016 .023 .017 .009 .007 .004 .004 .013 .032 .046 .046 .054 .052 .052 .049 .053 .052 .051 .047 .038 .018 .018 .016 .014 24  .054
  9  .015 .020 .012 .013 .014 .013 .016 .021 .035 .037 .045 .054 .059 .060 .058 .058 .061 .059 .057 .047 .043 .042 .044 .031 24  .061
 10  .017 .002 .001 .001 .003 .007 .004 .011 .026 .038 .036 .034 .047 .055 .059 .061 .061 .063 .058 .037 .023 .002 .001 .001 24  .063
 11  .007 .004 .017 .032 .043 .042 .031 .036 .047 .057 .063 .062 .055 .055 .054 .055 .053 .053 .050 .043 .045 .048 .045 .032 24  .063
 12  .028 .032 .029 .023 .031 .017 .010 .009 .017 .029 .037 .052 .060 .061 .063 .063 .061 .057 .055 .038 .026 .023 .022 .015 24  .063
 13  .020 .023 .022 .023 .019 .018 .019 .028 .032 .031 .034 .037 .045 .046 .047 .043 .042 .049 .046 .035 .027 .032 .038 .042 24  .049
 14  .041 .038 .035 .030 .026 .024 .018 .017 .011 .007 .007 .004 .008 .011 .014 .021 .022 .021 .027 .039 .033 .026 .015 .011 24  .041
 15  .017 .025 .024 .027 .027 .027 .024 .029 .038 .046 .050 .053 .053 .053 .054 .056 .057 .057 .056 .050 .042 .027 .031 .024 24  .057
 16  .023 .025 .012 .025 .019 .012 .008 .009 .017 .029 .042 .053 .054 .063 .065 .066 .065 .064 .058 .045 .036 .030 .019 .008 24  .066
 17  .005 .002 .009 .023 .029 .019 .017 .030 .032 .039 .043 .043 .051 .057 .060 .052 .056 .059 .053 .046 .027 .016 .010 .005 24  .060
 18  .006 .020 .020 .023 .023 .011 .015 .020 .030 .035 .047 .053 .052 .050 .054 .055 .059 .057 .054 .049 .033 .027 .024 .026 24  .059
 19  .032 .033 .026 .014 .014 .008 .007 .012 .015 .022 .031 .047 .054 .061 .062 .066 .061 .063 .063 .055 .034 .026 .015 .005 24  .066
 20  .001 .002 .002 .002 .001 .002 .003 .012 .049 .062 .068 .074 .077 .082 .091 .097 .096 .094 .088 .072 .047 .010 .005 .003 24  .097
 21  .001 .001 .001 .001 .002 .002 .006 .022 .050 .061 .074 .082 .088 .096 .093 .095 .092 .087 .083 .075 .050 .032 .019 .005 24  .096
 22  .002 .001 .007 .003 .002 .003 .019 .044 .064 .065 .074 .072 .077 .079 .076 .073 .078 .076 .067 .059 .033 .014 .019 .003 24  .079
 23  .004 .001 .002 .004 .004 .006 .005 .018 .043 .062 .065 .072 .079 .074 .074 .070 .068 .066 .056 .046 .032 .036 .039 .004 24  .079
 24  .016 .027 .028 .025 .019 .015 .020 .044 .042 .053 .074 .078 .078 .079 .074 .076 .077 .073 .064 .055 .042 .055 .054 .039 24  .079
 25  .032 .033 .032 .026 .022 .025 .022 .028 .032 .040 .052 .061 .071      .067 .064 .064 .064 .054 .047 .042 .028 .043 .033 23  .071
 26  .030 .021 .025 .029 .027 .023 .022 .027 .036 .042 .038 .037 .038 .039 .041 .040 .042 .042 .041 .038 .034 .027 .019 .015 24  .042
 27  .013 .011 .015 .014 .010 .005 .005 .013 .019 .030 .037 .044 .050 .052 .055 .059 .062 .060 .059 .046 .036 .029 .004 .002 24  .062
 28  .001 .001 .001 .001 .001 .002 .004 .014 .038 .057 .065 .066 .066 .065 .063 .061 .058 .058 .052 .054 .040 .023 .015 .012 24  .066
 29  .012 .008 .013 .016 .022 .022 .022 .041 .059 .066 .070 .071 .070 .069 .069 .066 .064 .065 .062 .056 .045 .031 .031 .040 24  .071
 30  .050 .042 .033 .029 .015 .020 .027 .025 .029 .029 .028 .027 .037 .052 .053 .048 .052 .051 .047 .042 .033 .027 .018 .014 24  .053
 31  .018 .024 .016 .012 .011 .010 .026 .028 .031 .038 .043 .048 .047 .051 .051 .056 .050 .051 .054 .044 .034 .027 .029 .030 24  .056

NO.    31   31   31   31   31   31   31   31   31   31   31   31   31   30   31   31   31   31   31   31   31   31   31   31
MAX  .050 .042 .036 .033 .043 .042 .031 .044 .064 .066 .074 .082 .088 .096 .093 .097 .096 .094 .088 .075 .050 .055 .054 .042
MEAN.017 .017 .016 .017 .016 .014 .014 .022 .032 .039 .045 .050 .054 .056 .057 .057 .057 .056 .053 .045 .033 .026 .022 .016

          MONTHLY OBSERVATIONS    743                          MONTHLY MEAN   .035                         MONTHLY MAXIMUM .097
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DATE: 11/03/95                        EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)                          PAGE     15
AMP350                                              AIR QUALITY SUBSYSTEM
                                                RAW DATA REPORT  1-HOUR LISTING
           (44201) OZONE                                                                      CAS NUMBER: 10028156
                                                 STATE (29): MISSOURI
                                                       JUN 1994

SITE-ID: 29-189-0006    POC: 1                   AQCR (070): METROPOLITAN ST. LOUIS               LATITUDE:  38:36:49 N
COUNTY (189):    ST LOUIS CO                     URBAN-AREA (0000):NOT IN AN URBAN AREA           LONGITUDE: 90:29:45 W
CITY (00000):    NOT IN A CITY                   LAND USE (1): RESIDENTIAL                        UTM ZONE: 15
SITE ADDRESS:    305 WEIDMAN ROAD (QUEENY)       LOCATION SETTING (3): RURAL                      UTM-NORTHING: 4276698
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO                                    UTM-EASTING:    718034
SITE COMMENTS:   ILLINOIS GRID 406 E 708 N                                                        ELEVATION-MSL:   175 M
MONITOR COMMENTS: 11                                                                              PROBE HEIGHT:      4 M
MONITOR TYPE (2): SLAMS                          MINIMUM DETECTABLE:        .005                  INTERVAL: 1
UNITS (007): PPM                                 REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

DAY/HOUR
     0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 OBS MAX
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  1  .025 .023 .017 .015 .013 .008 .005 .016 .021 .026 .027 .043 .053 .062 .079 .087 .088 .083 .093 .072 .042 .046 .043 .042 24 .093
  2  .035 .028 .031 .027 .024 .019 .016 .024 .027 .030 .031 .019 .019 .019 .018 .019 .019 .018 .024 .023 .020 .021 .018 .019 24 .035
  3  .020 .015 .013 .012 .016 .015 .006 .004 .006 .005 .006 .015 .027 .028 .033 .041                                         16 .041
  4  .002 .002 .003 .004 .004 .003 .005 .024                                         .096 .107 .093 .086 .064 .038 .025 .019 16 .107
  5  .009 .006 .006 .004 .004 .007 .009 .029 .055 .069 .066 .060 .059 .057 .064 .066                                         16 .069
  6  .002 .011 .016 .020 .025 .014 .014 .031 .047 .059 .065 .071 .085 .099 .103 .109 .088 .072 .057 .047 .045 .044 .043 .037 24 .109
  7  .032 .034 .028 .018 .011 .007 .012 .028 .047 .054 .069 .083 .088 .094 .097 .057 .070 .064 .062 .051 .045 .047 .035 .025 24 .097
  8  .011 .003 .001 .001 .003 .008 .006 .004 .004 .007 .007 .008           .041 .030 .025 .016 .021 .019 .012 .011 .009 .011 22 .041
  9  .009 .007 .005 .002 .001 .002 .002 .003 .004 .008 .009 .012 .018 .019 .014 .030 .033 .033 .040 .033 .027 .038 .039 .039 24 .040
 10  .040 .033 .028 .022 .027 .025 .022 .029 .035 .049 .052 .046 .047 .056 .057 .065 .068 .066 .063 .057 .044 .010 .010 .011 24 .068
 11  .019 .012 .011 .004 .007 .003 .011 .024 .037 .056 .064 .066 .070 .069 .067 .071 .063 .070 .073 .058 .042 .031 .023 .008 24 .073
 12  .008 .014 .028 .034 .029 .025 .024 .026 .037 .049 .049 .048 .047 .044 .043 .043 .042 .041 .040 .035 .025 .032 .046 .047 24 .049
 13  .042 .042 .039 .036 .036 .031 .024 .029 .035 .039 .040 .043 .042 .040 .035 .035 .036 .033 .029 .024 .020 .026 .028 .025 24 .043
 14  .023 .019 .016 .016 .011 .011 .010 .031 .033 .035 .035 .036 .037 .035 .034 .032 .032 .032 .031 .027 .025 .025 .025 .030 24 .037
 15  .032 .033 .035 .033 .029 .023 .014 .031 .035      .035 .037 .036 .036 .036 .035 .033 .033 .029 .025 .018 .013 .017 .019 23 .037
 16  .023 .022 .024 .018 .007 .005 .002 .002 .024 .048 .058 .056 .054 .051 .055 .048 .040 .038 .044 .039 .042 .047 .045 .037 24 .058
 17  .024 .017 .021 .019 .010 .007 .005 .020 .042 .048 .075 .110 .116 .123 .129 .118 .096 .083 .055 .043 .041 .033 .022 .015 24 .129
 18  .011 .011 .007 .008 .013 .016 .015 .026 .043 .050 .069 .110 .122 .118 .128 .126 .104 .086 .051 .078 .071 .070 .056 .054 24 .128
 19  .041 .017 .012 .010 .005 .005 .008 .031 .057 .079 .098 .107 .112 .122 .129 .113 .110 .099 .090 .084 .074 .059 .054 .046 24 .129
 20  .038 .025 .025 .029 .021 .016 .011 .029 .052 .073 .095 .112 .118 .101 .098 .086 .076 .072 .069 .068 .051 .053 .046 .042 24 .118
 21  .042 .045 .042 .040 .034 .025 .013 .034 .045 .063 .072 .083 .087 .080 .081 .077 .073 .076 .072 .065 .061 .057 .041 .025 24 .087
 22  .026 .024 .011 .015 .012 .009 .009 .020 .038 .083 .090 .089 .085 .081 .067 .055 .067 .051 .018 .026 .019 .008 .001 .000 24 .090
 23  .001 .010 .010 .002 .012 .014 .016 .024 .035 .041 .047 .056 .051 .052 .054 .053 .050 .037 .040 .040 .034 .036 .036 .035 24 .056
 24  .042 .037 .040 .043 .042 .038 .036 .039 .040 .046 .053 .055 .054 .051 .051 .050 .050 .051 .048 .038 .031 .022 .020 .021 24 .055
 25  .005 .000 .002 .002 .002 .001 .007 .029 .043 .055 .059 .062 .062 .066 .065 .068 .067 .068 .061 .046 .030 .022 .022 .046 24 .068
 26  .051 .040 .036 .036 .033 .027 .036 .041 .036 .038 .047 .051 .056 .060 .059 .046 .049 .042 .026 .018 .018 .026 .017 .008 24 .060
 27  .013 .016 .015 .010 .005 .002 .007 .016 .028 .043 .064 .091 .107 .085 .081 .066 .055 .062 .067 .058 .029 .014 .008 .012 24 .107
 28  .011 .010 .013 .010 .008 .011 .021 .041 .048 .051 .053 .056 .051 .054 .052 .052 .058 .058 .049 .057 .053 .044 .036 .041 24 .058
 29  .034 .034 .020 .019 .038 .035 .033 .035 .039 .044 .045 .045 .045 .046 .047 .047 .048 .048 .046 .045 .042 .033 .030 .010 24 .048
 30  .022 .020 .017 .014 .016 .007 .003 .013 .025 .039 .055 .068 .076 .073 .074 .072 .078 .080 .079 .071 .044 .018 .002 .000 24 .080
 31

NO.    30   30   30   30   30   30   30   30   29   28   29   29   28   28   29   29   28   28   28   28   28   28   28   28
MAX  .051 .045 .042 .043 .042 .038 .036 .041 .057 .083 .098 .112 .122 .123 .129 .126 .110 .107 .093 .086 .074 .070 .056 .054
MEAN .023 .020 .019 .017 .017 .014 .013 .024 .035 .046 .053 .060 .065 .065 .065 .062 .061 .058 .053 .048 .038 .033 .029 .026

        MONTHLY OBSERVATIONS   693                      MONTHLY MEAN  .039                       MONTHLY MAXIMUM .129
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DATE: 11/03/95
AMP350

EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
RAW DATA REPORT 1-HOUR LISTING

PAGE 16

(44201) OZONE

CAS NUMBER: 10028156

STATE (29): MISSOURI
JUL 1994

SITE-ID: 29-189-0006 POC: 1
COUNTY (189): ST LOUIS CO
CITY (00000): NOT IN A CITY
SITE ADDRESS: 305 WEIDMAN ROAD (QUEENY)
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO
SITE COMMENTS: ILLINOIS GRID 406 E 708 N
MONITOR COMMENTS: 11
MONITOR TYPE (2): SLAMS
UNITS (007): PPM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

AQCR (070): METROPOLITAN ST. LOUIS
URBAN-AREA (0000):NOT IN AN URBAN AREA
LAND USE (1): RESIDENTIAL
LOCATION SETTING (3): RURAL

MINIMUM DETECTABLE: .005
REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM

LATITUDE: 38:36:49 N
LONGITUDE: 90:29:45 W
UTM ZONE: 15
UTM-NORTHING: 4276698
UTM-EASTING: 718034
ELEVATION-MSL: 175 M
PROBE HEIGHT: 4 M
INTERVAL: 1

DAY/HOUR	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	OBS	MAX
1	.004	.008	.002	.000	.002	.004	.005	.032	.050	.059	.071	.073	.063	.066	.063	.054	.057	.054	.048	.042	.034	.024	.012	.011	24	.073
2	.008	.007	.014	.026	.022	.022	.021	.032	.043	.049	.056	.059	.057	.055	.047	.048	.035	.042	.037	.033	.030	.024	.026	.018	24	.059
3	.018	.023	.027	.020	.017	.022	.020	.019	.022	.039	.053	.064	.068	.078	.076	.062	.069	.078	.078	.078	.054	.031	.025	.022	24	.078
4	.017	.015	.012	.012	.011	.016	.028	.042	.044	.046	.046	.048	.050	.051	.048	.048	.048	.045	.042	.037	.032	.031	.041	.044	24	.051
5	.046	.046	.044	.040	.038	.033	.035	.042	.051	.066	.070	.060	.058	.057	.054	.053	.050	.051	.042	.030	.017	.017	.012	.018	24	.070
6	.015	.009	.012	.022	.034	.025	.024	.030	.036	.048	.059	.058	.051	.047	.043	.043	.042	.042	.039	.031	.027	.012	.014	.030	24	.059
7	.027	.035	.031	.027	.024	.019	.011	.022	.036	.038	.038	.049	.057	.050	.023	.013	.004	.004	.014	.008	.026	.024	.024	.027	24	.057
8	.020	.010	.008	.009	.020	.037	.016	.016	.033	.039	.055	.053	.050	.047	.042	.039	.039	.039	.038	.030	.016	.018	.016	.017	24	.055
9	.015	.009	.004	.002	.003	.004	.011	.027	.034	.042	.043	.049	.049	.050	.050	.049	.045	.044	.041	.030	.031	.019	.005	.005	24	.050
10	.002	.004	.013	.009	.006	.005	.014	.024	.034	.038	.045	.049	.055	.060	.060	.061	.062	.057	.045	.046	.046	.028	.014	.006	24	.062
11	.002	.000	.000	.000	.002	.002	.001	.005	.025	.052	.066	.073	.081	.070	.080	.082	.076	.083	.072	.078	.051	.027	.017	.009	24	.083
12	.007	.010	.008	.014	.023	.017	.031	.029	.032	.065	.085	.092	.090	.092	.086	.078	.082	.077	.068	.062	.046	.038	.045	.047	24	.092
13	.029	.027	.024	.010	.001	.001	.002	.020	.035	.052	.063	.069	.076	.076	.076	.067	.060	.057	.045	.041	.042	.039	.040	.040	24	.076
14	.031	.022	.030	.032	.024	.020	.020	.015	.023	.040	.061	.056	.059	.068	.066	.052	.043	.042	.037	.031	.027	.039	.039	.046	24	.068
15	.046	.039	.032	.026	.027	.025	.012	.024	.030	.041	.053	.065	.074	.082	.081	.079	.079	.073	.062	.047	.029	.012	.011	.006	24	.082
16	.016	.013	.011	.011	.008	.006	.010	.018	.036	.061	.074	.056	.041	.023	.023	.042	.046	.039	.036	.034	.024	.013	.010	.004	24	.074
17	.005	.008	.012	.010	.006	.005	.014	.038	.052	.061	.062	.061	.062	.066	.055	.048	.049	.046	.043	.039	.035	.030	.030	.027	24	.066
18	.013	.005	.006	.008	.010	.002	.003	.009	.023	.050	.062	.071	.073	.073	.079	.090	.083	.085	.070	.057	.035	.019	.019	.012	24	.090
19	.008	.006	.007	.012	.011	.010	.008	.026	.039	.048	.055	.060	.063	.057	.058	.060	.061	.057	.051	.036	.030	.026	.042	.050	24	.063
20	.052	.051	.049	.044	.039	.034	.033	.035	.041	.051	.061	.063	.077	.076	.068	.064	.063	.057	.042	.022	.021	.020	.021	.014	24	.077
21	.022	.018	.016	.018	.021	.025	.016	.016	.022	.030	.036	.047	.044	.037	.050	.054	.054	.051	.043	.037	.035	.042	.044	.038	24	.054
22	.030	.024	.017	.019	.018	.010	.019	.027	.034	.041	.046	.046	.046	.048	.046	.046	.046	.045	.033	.028	.026	.023	.017	.019	24	.048
23	.018	.018	.023	.019	.012	.006	.015	.028	.034	.043	.052	.054	.054	.052	.045	.047	.045	.045	.042	.047	.026	.008	.005	.000	24	.054
24	.001	.000	.000	.000	.001	.001	.006	.013	.031	.042	.049	.044	.061	.047	.040	.049	.047	.046	.041	.034	.028	.020	.020	.021	24	.061
25	.018	.010	.007	.014	.005	.002	.009	.018	.029	.042	.052	.058	.053	.052	.054	.056	.055	.052	.046	.043	.022	.013	.004	.006	24	.058
26	.000	.001	.006	.013	.013	.008	.003	.003	.011	.018	.020	.024	.026	.020	.021	.015	.014	.013	.019	.015	.012	.007	.009	.012	24	.026
27	.012	.014	.014	.014	.015	.011	.009	.009	.019	.028	.034	.038	.033	.038	.039	.043	.033	.033	.034	.023	.012	.003	.001	.002	24	.043
28	.006	.008	.007	.006	.005	.003	.003	.008	.019	.031	.039	.037	.046	.052	.053	.051	.047	.046	.041	.040	.027	.018	.002	.000	24	.053
29	.000	.000	.000	.000	.000	.000	.001	.006	.024	.038	.048	.051	.057	.057	.059	.062	.059	.058	.055	.043	.018	.010	.001	.000	24	.062
30	.000	.000	.000	.005	.000	.000	.000	.009	.029	.040	.046	.053	.053	.040	.043	.046	.045	.045	.040	.044	.040	.033	.026	.022	24	.053
31	.022	.016	.021	.015	.015	.018	.015	.030	.050	.056	.058	.060	.059	.057	.058	.060	.058	.059	.060	.050	.044	.031	.027	.022	24	.060
NO.	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31		
MAX	.052	.051	.049	.044	.039	.037	.035	.042	.052	.066	.085	.092	.090	.092	.086	.090	.083	.085	.078	.078	.054	.042	.045	.050		
MEAN	.017	.015	.015	.015	.014	.013	.014	.022	.033	.045	.053	.056	.058	.056	.054	.054	.051	.050	.045	.039	.030	.023	.020	.019		

MONTHLY OBSERVATIONS 744
MONTHLY MEAN .034
MONTHLY MAXIMUM .092

BEST COPY AVAILABLE

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DATE: 11/03/95                                      EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)                                   PAGE      17
AMP350                                                             AIR QUALITY SUBSYSTEM
                                                             RAW DATA REPORT  1-HOUR LISTING
              (44201) OZONE                                                                                        CAS NUMBER: 10028156
                                                                 STATE (29): MISSOURI
                                                                       AUG 1994

SITE-ID: 29-189-0006     POC: 1                          AQCR (070): METROPOLITAN ST. LOUIS                                LATITUDE:  38:36:49 N
COUNTY (189):    ST LOUIS CO                             URBAN-AREA (0000):NOT IN AN URBAN AREA                            LONGITUDE: 90:29:45 W
CITY (00000):    NOT IN A CITY                           LAND USE (1): RESIDENTIAL                                         UTM ZONE: 15
SITE ADDRESS:    305 WEIDMAN ROAD (QUEENY)               LOCATION SETTING (3): RURAL                                       UTM-NORTHING: 4276698
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO                                                             UTM-EASTING:    718034
SITE COMMENTS:  ILLINOIS GRID 406 E 708 N                                                                                  ELEVATION-MSL:    175 M
MONITOR COMMENTS: 11                                                                                                       PROBE HEIGHT:       4 M
MONITOR TYPE (2): SLAMS                                  MINIMUM DETECTABLE:        .005                                   INTERVAL: 1
UNITS (007): PPM                                         REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

DAY/HOUR
     0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 OBS MAX
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 1   .013 .008 .008 .005 .004 .001 .002 .021 .040 .045 .062 .079 .073 .070 .073 .077 .070 .054 .039 .026 .023 .027 .024 .015 24 .079
 2   .011 .016 .021 .019 .012 .007 .010 .005 .002 .011 .039 .055 .066 .080 .087 .080 .082 .076 .073 .068 .035 .023 .013 .009 24 .087
 3   .009 .008 .010 .014 .009 .004 .003 .016 .043 .050 .057 .059 .062 .063 .061 .060 .058 .049 .031 .016 .007 .004 .011 .031 24 .063
 4   .035 .037 .036 .035 .033 .030 .028 .027 .035 .034 .042 .045 .048 .054 .054 .056 .057 .057 .045 .045 .031 .025 .029 .024 24 .057
 5   .022 .021 .021 .021 .018 .014 .013 .018 .022 .021 .030 .038 .040 .042 .044 .044 .042 .038 .039 .036 .026 .015 .012 .009 24 .044
 6   .007 .008 .013 .005 .001 .002 .003 .007 .022 .039 .050 .057 .066 .071 .072 .065 .064 .066 .067 .064 .043 .019 .009 .003 24 .072
 7   .005 .013 .016 .010 .003 .004 .007 .025 .038 .054 .062 .064 .065 .063 .068 .068 .069 .074 .067 .044 .041 .039 .035 .027 24 .074
 8   .023 .025 .029 .034 .032 .025 .030 .030 .042 .051 .061 .064 .074 .077 .075 .075 .073 .062 .057 .057 .050 .039 .033 .036 24 .077
 9   .033 .033 .028 .023 .012 .008 .011 .025 .034 .029 .045 .069 .078 .077 .050 .071 .058 .045 .046 .041 .040 .031 .029 .026 24 .078
10   .031 .032 .028 .028 .027 .018 .009 .006 .012 .018 .042 .072 .081 .077 .071 .063 .055 .053 .052 .057 .047 .036 .027 .018 24 .081
11   .029 .037 .040 .044 .045 .038 .023 .020 .028 .051 .061 .066 .065 .068 .070 .062 .057 .057 .046 .038 .032 .024 .019 .018 24 .070
12   .011 .010 .009 .005 .001 .000 .001 .002 .007 .017 .041 .087 .092 .078 .087 .080 .054 .040 .038 .036 .023 .019 .046 .052 24 .092
13   .055 .059 .057 .056 .056 .056 .053 .056 .062 .067 .069 .067 .066 .063 .059 .059 .061 .056 .049 .051 .054 .029 .053 .057 24 .069
14   .034 .033 .041 .043 .037 .024 .024 .027 .029 .032 .038 .042 .047 .047 .046 .045 .043 .040 .037 .035 .026 .024 .027 .021 24 .047
15   .020 .020 .016 .009 .008 .003 .003 .011 .014 .027 .036 .043 .056 .065 .071 .075 .073 .064 .055 .044 .028 .017 .014 .013 24 .075
16   .004 .000 .000 .003 .003 .000 .001 .002 .014 .038 .044 .057 .065 .079 .099 .104 .100 .088 .082 .075 .043 .026 .006 .000 24 .104
17   .000 .000 .000 .000 .000 .000 .001 .005 .031 .056 .063 .082 .108 .132 .145 .158 .164 .134 .099 .091 .056 .036 .016 .008 24 .164
18   .010 .004 .015 .031 .018 .006 .001           .042 .086 .117 .117 .125 .128 .120 .110 .097 .073 .053 .045 .034 .029 .021 22 .128
19   .012 .007 .017 .024 .034 .028 .021 .008 .024 .046 .049 .059 .059 .062 .072 .084 .078 .067 .056 .050 .049 .050 .048 .047 24 .084
20   .041 .040 .037 .036 .028 .026 .030 .027 .026 .028 .027 .032 .032 .045 .057 .050 .062 .061 .054 .044 .042 .029 .025 .025 24 .062
21   .024 .021 .020 .018 .016 .016 .017 .021 .026 .033 .041 .047 .049 .050 .046 .044 .047 .045 .039 .033 .027 .013 .003 .000 24 .050
22   .001 .003 .008 .004 .001 .000 .001 .001 .009 .015 .024 .033 .044 .059 .059 .065 .067 .055 .046 .035 .023 .007 .000 .000 24 .067
23   .000 .000 .003 .000 .000 .000 .000 .000 .004 .033 .064 .065 .063 .067 .068 .068 .068 .061 .051 .036 .031 .023 .017 .016 24 .068
24   .017 .010 .009 .006 .001 .001 .000 .019 .048 .060 .070 .069 .067 .068 .068 .066 .064 .061 .055 .041 .031 .024 .022 .025 24 .070
25   .045 .048 .049 .045 .037 .033 .017 .041 .059 .066 .074 .077 .073 .088 .101 .103 .088 .073 .050 .045 .037 .038 .031 .034 24 .103
26   .043 .038 .026 .013 .013 .018 .004 .009 .036 .061 .065 .070 .070 .072 .074 .076 .056 .047 .054 .045 .030 .020 .010 .005 24 .076
27   .000 .000 .000 .000 .000 .000 .001 .012 .039 .054 .059 .059 .062 .060 .056 .055 .053 .048 .044 .043 .048 .056 .058 .059 24 .062
28   .058 .057 .055 .053 .051 .050 .046 .045 .051 .058 .062 .068 .069 .068 .069 .066 .047 .044 .042 .036 .035 .031 .025 .029 24 .069
29   .030 .021 .009 .010 .016 .009 .004 .003 .008 .012 .012 .012 .023 .026 .037 .037 .037 .023 .017 .019 .004 .007 .017 .015 24 .037
30   .012 .009 .018 .023 .017 .006 .001 .004 .004 .010 .023 .033 .024 .014 .020 .022 .017 .009 .022 .024 .027 .025 .024 .031 24 .033
31   .030 .030 .026 .033 .033 .036 .030 .025 .028 .024 .028 .040 .046 .047 .047 .049 .043 .039 .033 .030 .030 .033 .028 .021 24 .049

NO.    31   31   31   31   31   31   31   30   30   31   31   31   31   31   31   31   31   31   31   31   31   31   31   31
MAX  .058 .059 .057 .056 .056 .056 .053 .056 .062 .067 .086 .117 .117 .132 .145 .158 .164 .134 .099 .091 .056 .056 .058 .059
MEAN.022 .021 .022 .021 .019 .015 .013 .017 .028 .038 .049 .059 .063 .066 .069 .069 .065 .058 .050 .044 .034 .027 .024 .023

          MONTHLY OBSERVATIONS   742                         MONTHLY MEAN  .038                            MONTHLY MAXIMUM .164
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EPA AEROMETRIC INFORMATION RETRIEVAL SYSTEM (AIRS)
AIR QUALITY SUBSYSTEM
RAW DATA REPORT 1-HOUR LISTING

(44201) OZONE

CAS NUMBER: 10028156

STATE (29): MISSOURI
SEP 1994

SITE-ID: 29-189-0006 POC: 1
COUNTY (189): ST LOUIS CO
CITY (00000): NOT IN A CITY
SITE ADDRESS: 305 WEIDMAN ROAD (QUEENY)
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO
SITE COMMENTS: ILLINOIS GRID 406 E 708 N
MONITOR COMMENTS: 11
MONITOR TYPE (2): SLAMS
UNITS (007): PPM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

AQCR (070): METROPOLITAN ST. LOUIS
URBAN-AREA (0000):NOT IN AN URBAN AREA
LAND USE (1): RESIDENTIAL
LOCATION SETTING (3): RURAL

MINIMUM DETECTABLE: .005
REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM

LATITUDE: 38:36:49 N
LONGITUDE: 90:29:45 W
UTM ZONE: 15
UTM-NORTHING: 4276698
UTM-EASTING: 718034
ELEVATION-MSL: 175 M
PROBE HEIGHT: 4 M
INTERVAL: 1

DAY/HOUR	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	OBS	MAX
1	.014	.013	.013	.012	.006	.003	.001	.002	.004	.009	.010	.009	.011	.007	.013	.021	.020	.022	.017	.005	.000	.000	.000	.000	24	.022
2	.001	.002	.004	.004	.008	.006	.002	.003	.010	.025	.034	.038	.044	.048	.046	.046	.045	.044	.040	.016	.010	.013	.013	.012	24	.048
3	.008	.007	.011	.006	.006	.013	.014	.016	.021	.032	.040	.055	.056	.063	.064	.061	.060	.060	.047	.039	.033	.039	.040	.034	24	.064
4	.037	.034	.029	.034	.035	.033	.027	.026	.030	.029	.035	.038	.050	.056	.064	.064	.067	.069	.056	.054	.057	.039	.026	.028	24	.069
5	.024	.020	.018	.023	.021	.028	.024	.025	.025	.026	.034	.043	.040	.040	.043	.042	.037	.040	.037	.035	.035	.031	.029	.026	24	.043
6	.032	.028	.025	.026	.021	.018	.012	.018	.027	.034	.042	.047	.049	.052	.057	.055	.057	.054	.046	.033	.033	.029	.013	.006	24	.057
7	.001	.002	.000	.000	.000	.000	.000	.003	.022	.042	.051	.052	.059	.063	.065	.062	.058	.052	.046	.031	.036	.019	.009	.000	24	.065
8	.004	.004	.000	.000	.000	.000	.000	.001	.014	.044	.064	.082	.091	.092	.090	.088	.093	.084	.077	.054	.018	.002	.000	.000	24	.093
9	.000	.000	.001	.005	.004	.006	.001	.010	.040	.057	.067	.081	.096	.104	.101	.097	.089	.089	.082	.052	.025	.009	.000	.000	24	.104
10	.000	.000	.000	.004	.002	.003	.001	.006	.031	.059	.081	.088	.088	.093	.096	.093	.079	.076	.066	.037	.027	.014	.014	.004	24	.096
11	.000	.000	.000	.000	.001	.001	.002	.006	.042	.070	.089	.097	.100	.102	.098	.101	.098	.072	.052	.047	.042	.030	.019	.005	24	.102
12	.006	.006	.007	.001	.000	.000	.000	.001	.009	.035	.065	.085	.088	.087	.083	.077	.074	.067	.056	.037	.025	.015	.010	.000	24	.088
13	.000	.000	.000	.001	.005	.011	.005	.008	.047	.070	.075	.072	.068	.068	.063	.059	.057	.053	.045	.040	.036	.038	.038	.033	24	.075
14	.025	.039	.044	.045	.047	.043	.033	.039	.050	.057	.060	.062	.062	.060	.059	.058	.056	.053	.043	.040	.028	.022	.019	.024	24	.062
15	.022	.019	.028	.048	.049	.048	.045	.046	.059		.065	.068	.064	.063	.061	.064	.062	.067	.065	.053	.050	.044	.042	.042	23	.068
16	.057	.071	.072	.068	.061	.055	.041	.037	.052	.042		.061	.058	.054	.048	.045	.050	.056	.049	.044	.038	.029	.029	.028	23	.072
17	.028	.027	.029	.030	.027	.020	.011	.016	.018	.025	.031	.036	.038	.041	.043	.044	.042	.038	.036	.034	.027	.026	.025	.022	24	.044
18	.023	.019	.016	.014	.012	.011	.006	.013	.022	.032	.040	.042	.047	.054	.054	.052	.050	.048	.039	.029	.015	.021	.031	.021	24	.054
19	.014	.013	.009	.008	.007	.003	.002	.006	.013	.033	.043	.045	.054	.062	.064	.064	.064	.058	.042	.014	.001	.001	.000	.000	24	.064
20	.000	.000	.000	.000	.000	.000	.000	.000	.008	.040	.057	.062	.055	.062	.071	.073	.074	.067	.047	.025	.021	.004	.002	.000	24	.074
21	.000	.000	.000	.000	.000	.000	.000	.001	.008	.051	.068	.072	.073	.068	.065	.063	.059	.047	.037	.045	.032	.023	.021	.024	24	.073
22	.030	.054	.055	.039	.036	.024	.023	.026	.035	.043	.014	.005	.003	.006	.009	.011	.014	.006	.001	.000	.000	.000	.000	.002	24	.055
23	.004	.005	.006	.010	.009	.008	.008	.008	.012	.013	.018	.023	.024	.030	.035	.037	.034	.023	.007	.001	.000	.000	.000	.000	24	.037
24	.000	.000	.000	.000	.001	.000	.000	.002	.005	.020	.025	.015	.021	.030	.024	.023	.029	.025	.021	.016	.009	.000	.000	.000	24	.030
25	.007	.012	.019	.025	.029	.023	.020	.020	.025	.026	.032	.035	.032	.033	.037	.033	.030	.021	.011	.009	.001	.006	.002	.000	24	.037
26	.000	.005	.008	.008	.013	.014	.008	.009	.016	.015	.016	.019	.032	.016	.008	.010	.011	.011	.009	.011	.010	.011	.015	.013	24	.032
27	.015	.016	.018	.018	.018	.019	.014	.015	.020	.024	.029	.031	.037	.039	.043	.044	.041	.026	.012	.008	.000	.000	.000	.000	24	.044
28	.000	.007	.011	.014	.012	.014	.003	.007	.021	.029	.035	.039	.042	.043	.044	.043	.038	.024	.006	.000	.002	.000	.003	.001	24	.044
29	.000	.000	.000	.000	.000	.000	.000	.000	.003	.013	.035	.035	.042	.056	.059	.049	.039	.033	.019	.017	.018	.013	.017	.019	24	.059
30	.012	.012	.012	.014	.014	.010	.001	.001	.011	.050	.065	.073	.076	.076	.070	.066	.063	.058	.050	.047	.063	.072	.072	.073	24	.076
31																										
NO.	30	30	30	30	30	30	30	30	30	29	29	30	30	30	30	30	30	30	30	30	30	30	30	30		
MAX	.057	.071	.072	.068	.061	.055	.045	.046	.059	.070	.089	.097	.100	.104	.101	.101	.098	.089	.082	.054	.063	.072	.072	.073		
MEAN	.013	.014	.015	.016	.015	.014	.011	.013	.023	.036	.046	.050	.053	.056	.056	.055	.053	.048	.039	.029	.024	.019	.017	.015		

MONTHLY OBSERVATIONS 718 MONTHLY MEAN .030 MONTHLY MAXIMUM .104

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                                            AIR QUALITY SUBSYSTEM
                                      RAW DATA REPORT  1-HOUR LISTING
            (44201) OZONE                                                                     CAS NUMBER: 10028156
                                           STATE (29): MISSOURI
                                                OCT 1994

SITE-ID: 29-189-0006     POC: 1                   AQCR (070): METROPOLITAN ST. LOUIS                     LATITUDE:  38:36:49 N
COUNTY (189):    ST LOUIS CO                      URBAN-AREA (0000):NOT IN AN URBAN AREA                 LONGITUDE: 90:29:45 W
CITY (00000):    NOT IN A CITY                    LAND USE (1): RESIDENTIAL                              UTM ZONE: 15
SITE ADDRESS:    305 WEIDMAN ROAD (QUEENY)        LOCATION SETTING (3): RURAL                            UTM-NORTHING: 4276698
SUPPORT AGENCY (002): ST LOUIS COUNTY HEALTH DEPARTMENT AIR PO                                           UTM-EASTING:    718034
SITE COMMENTS:  ILLINOIS GRID 406 E 708 N                                                                ELEVATION-MSL:    175 M
MONITOR COMMENTS: 11                                                                                     PROBE HEIGHT:       4 M
MONITOR TYPE (2): SLAMS                           MINIMUM DETECTABLE:         .005                       INTERVAL: 1
UNITS (007): PPM                                  REPORTING ORGANIZATION (002): ST LOUIS COUNTY HEALTH DEPARTM
COLLECTION AND ANALYSIS METHOD (014): INSTRUMENTAL ULTRA VIOLET

DAY/HOUR
     0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 OBS MAX
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 1   .070 .069 .068 .065 .062 .058 .049 .050 .059 .060 .067 .076 .081 .082 .081 .080 .074 .063 .034 .022 .012 .001 .011 .023  24 .082
 2   .009 .020 .022 .018 .017 .014 .012 .014 .017 .022 .030 .046 .060 .079 .092 .092 .079 .064 .035 .028 .042 .044 .033 .029  24 .092
 3   .025 .021 .018 .017 .014 .009 .001 .003 .006 .010 .016 .022 .032 .034 .036 .035 .039 .031 .013 .010 .002 .001 .000 .002  24 .039
 4   .000 .001 .004 .002 .005 .003 .000 .000 .002 .005 .005 .014 .022 .034 .036 .030 .032 .028 .014 .006 .006 .000            22 .036
 5                                  .000 .000 .001 .008 .023 .035 .036 .039 .040 .042 .034 .021 .013 .006 .018 .021 .017 .015  18 .042
 6   .015 .020 .022 .021 .019 .014 .008 .016 .024 .038 .047 .054 .066 .073 .076 .076 .073 .066 .054 .049 .042 .047 .045 .042  24 .076
 7   .038 .040 .041 .037 .040 .037 .037 .045 .051 .053 .053 .053 .054 .059 .060 .056 .056 .059 .057 .054 .048 .046 .049 .050  24 .060
 8   .048 .047 .043 .042 .030 .011 .006 .005 .005 .009 .011 .017 .023 .023 .022 .018 .018 .013 .010 .010 .004 .006 .006 .006  24 .048
 9   .007 .010 .010 .015 .011 .010 .016 .017 .018 .023 .030 .034 .036 .037 .037 .037 .035 .030 .016 .004 .013 .008 .012 .011  24 .037
10   .005 .011 .012 .007 .001 .002 .002 .001 .005 .022 .030 .030 .034 .036 .032 .032 .033 .029 .012 .004 .002 .004 .006 .006  24 .036
11   .011 .010 .012 .010 .005 .001 .000 .001 .005 .015 .027 .034 .038 .038 .038 .036 .031 .021 .005 .000                .000  21 .038
12   .003 .007 .005 .001 .000      .000 .000 .002 .003 .006 .009 .016 .017 .018 .015 .009 .002      .002 .019 .019 .015 .012  22 .019
13   .012 .007 .011 .006 .007 .004 .003 .001 .001 .002 .007 .016 .022 .018 .017 .018 .008 .006 .014 .004 .000           .000  22 .022
14   .000                           .000 .000 .000 .000 .000 .002 .007 .013 .013 .009 .004 .006 .004 .000 .000 .000 .000       18 .013
15   .000 .002 .003 .005 .002      .001 .001 .003 .005 .005 .006 .008 .009 .010 .010 .013 .015 .009 .007 .012 .014 .011 .014  23 .015
16   .015 .008 .009 .008 .007 .004 .005 .007 .013 .021 .029 .037 .043 .046 .044 .043 .042 .039 .036 .035 .028 .025 .023 .023  24 .046
17   .025 .027 .021 .027 .028 .023 .015 .016 .026 .035 .044 .039 .032 .023 .020 .019 .021 .021 .026 .027 .026 .029 .031 .031  24 .044
18   .031 .030 .028 .025 .023 .019 .013 .011 .009 .012 .017 .017 .018 .014 .006 .002 .002 .004 .005 .003 .001 .000 .000       23 .031
19        .000 .004 .005 .005 .003 .000 .002 .009 .020 .028 .038 .045 .045 .044 .044 .040 .022 .012 .017 .016 .014 .001 .003  23 .045
20   .026 .026 .023 .020 .019 .002 .001 .001 .003 .010 .036 .043 .047 .050 .051 .048 .042 .031 .034 .021 .006 .000 .000 .000  24 .051
21        .000 .000 .000 .000      .000 .000 .001 .009 .031 .040 .048 .049 .039 .024 .019 .009 .008 .011 .015 .016 .014 .010  22 .049
22   .007 .004 .003 .007 .011 .010 .008 .003 .002 .017 .035 .042 .055 .059 .056 .056 .050 .031 .024 .026 .025 .025 .032 .029  24 .059
23   .027 .024 .025 .024 .025 .024 .020 .014 .025 .028 .032 .036 .038 .040 .041 .041 .038 .029 .025 .023 .025 .017 .026 .026  24 .041
24   .026 .022 .033 .026 .019 .014 .006 .001 .007 .015 .023 .022 .029 .033 .035 .036 .035 .023 .016 .022 .020 .020 .025 .023  24 .036
25   .022 .021 .023 .023 .019 .011 .002 .001 .018 .023 .026 .027 .029 .031 .032 .032 .029 .018 .002 .009 .017 .017 .013 .011  24 .032
26   .009 .011 .007 .010 .003 .000 .000 .001 .005 .013 .017 .022 .024 .026 .027 .024 .023 .013 .004 .000                      20 .027
27             .000 .000                     .000 .003 .008 .018 .033 .038 .042 .043 .036 .026 .016 .009 .007 .001 .000 .003  18 .043
28   .007 .011 .006 .012 .012 .001 .000 .002 .013 .031 .035 .040 .044 .047 .047 .045 .042 .038 .033 .040 .042 .046 .049 .051  24 .051
29   .050 .049 .052 .051 .053 .051 .049 .044 .048 .052 .054 .059 .063 .065 .062 .059 .056 .047 .041 .027 .020 .011 .001 .013  24 .065
30   .007 .007 .011 .008 .000 .004 .000 .002 .006 .016 .025 .029 .031 .040 .047 .045 .030 .010 .005 .001 .000 .006 .020 .024  24 .047
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          MONTHLY OBSERVATIONS    708                        MONTHLY MEAN   .022                    MONTHLY MAXIMUM .092
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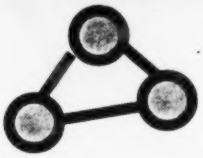
Part 2

Stratospheric Ozone

Snowmass Showdown[1]



Name: ____________________

Date: ____________________

Period: ____________________

OBJECTIVES

- Students will apply information about reaction rates to the issue of ozone depletion.
- Students will defend a position regarding stratospheric ozone depletion.
- Students will reenact the historical progression of ozone depletion discoveries.

MATERIALS

- Scientist biographies
- NASA color transparencies of the ozone hole
- Overhead projector

The Polar Ozone Workshop was a 5 day scientific gathering that took place May 9-13, 1988 in Snowmass Village, Colorado. Over 200 scientists and several media representatives attended. The event provided a rare opportunity for almost every scientist with expertise related to the ozone crisis to meet with each other and hash out differing points of view. The event was a spirited one, with plenty of disagreement between scientists, as they sought to solve the riddle of ozone depletion. Is it happening? What's causing it? How is it happening? What will happen in the future? What should be done about it?

Your class will assemble a mock reenactment of the conference.

Presenters

Joe Farman **Mario Molina** **Susan Soloman**

Don Heath **Bob Watson**

Sherry Rowland **Jim Anderson**

The responsibility of the presenters will be to read the description regarding their personality and prepare a 5-10 minute oral presentation, following the instructions given at the end of each description.

Reporters

The responsibility of the reporters is to write articles reporting on the scientists' presentations. The articles should answer the questions who, what, where, when, and why. They should explain the underlying scientific principles involved, and how those scientific principles relate to ozone depletion. Finally, the articles should be written with the appropriate audience in mind.

Newsweek reporters should write for the general public.

National Enquirer reporters should write for bored supermarket shoppers.

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[1] **Reference:** *Nance, John J. 1991.* What Goes Up: The Global Assault on our Atmosphere, 1st ed. *New York: W. Morrow.*

Scientific American reporters should write for the scientific community.

Wall Street Journal reporters should write for the business community.

Report on Joe Farman

Make sure your readers understand what a "rate" and a "reaction rate" are, and what they have to do with ozone.

Report on Don Heath

Make sure your readers understand the significance of the satellite data presented by Don Heath as well as the effects of ozone depletion on human health.

Report on Sherry Rowland

Make sure your readers understand how the nature of the reactants can affect the rate of a reaction and what that has to do with the Rowland-Molina Theory.

Report on Mario Molina

Make sure your readers understand what a chemical "sink" is, and what that has to do with ozone depletion. Discuss the pros and cons of an immediate ban on CFC's and chlorine containing substitutes.

Report on Bob Watson

Make sure your readers understand the effects of temperature and concentration on reaction rates, and the relationship of each to answering the question of what caused the Antarctic ozone hole.

Report on Jim Anderson

Make sure your readers understand what a catalyst is, and its importance in relation to ozone depletion.

Report on Susan Solomon

Make sure your readers understand how heterogeneous catalysts and the amount of exposed surface area can affect the rate of a chemical reaction. Explain why ozone depletion occurs so much more rapidly in Antarctica than elsewhere on the planet. Could what happened in Antarctica potentially happen somewhere else? Why or why not?

Snowmass Showdown TEACHER BACKGROUND

OBJECTIVES

- Students will apply information about reaction rates to the issue of ozone depletion.
- Students will defend a position regarding stratospheric ozone depletion.
- Students will reenact the historical progression of ozone depletion discoveries.

MATERIALS

- Scientist biographies
- NASA color transparencies of the ozone hole
- Overhead projector

To receive a color photograph entitled: "Nimbus-7 TOMS Images: The 12 Octobers" point your web browser to: http://jwocky.gsfc.nasa.gov/oct15.gif Or, contact NASA's Education Distribution Center at 1 (202) 453-1287. Ask for card #HqL-308. You will need to make your own color transparency from the color photo so that the student role-playing Don Heath can effectively display it to the class.

SCIENCE SKILLS

- Communicating Results

Assign seven students the roles of the various scientists. Give each student a copy of the write-up that corresponds to the presentation they will make. Some of the presenters will also need copies of the BIOS of certain scientists that precede them at the conference, as background information. Refer to the text to identify which scientists need this.

It is recommended that all the students **not** be given a copy of all the scientist descriptions. This will force the students to rely on their ability to digest the information as it is presented by their peers.

Assign the remaining students the role of reporter from the publication of your or their choice.

Student learning can be assessed according to the quality of the scientist presentations, and the quality of the articles written by the reporters.

If time allows, you may want to assemble the best student articles into a "newspaper", to be distributed on subsequent days of the conference. This provides an additional avenue for reinforcing the concepts presented, and also adds to the role-play atmosphere.

Joe Farman

Your scientific career began in 1957 when you joined the British Antarctic Survey, and you have been studying the Antarctic atmosphere ever since. Year in and year out you make the pilgrimage to cold and lonely scientific outposts, where you collect and analyze atmospheric data. You are always on the go, and your craggy face reflects the icy wilderness you have come to know so well.

In 1981, you began to notice extraordinarily low levels of stratospheric ozone. The figures were so low you could scarcely believe them. Were your measurements accurate? Where your findings correct? You weren't sure.

Your British team was not the only group studying ozone levels in Antarctica at the time. The Americans and the Japanese had sent teams South as well. You wondered quizzically why *they* hadn't observed and reported similar discoveries.

Should you publish what you had found out, or not? If your findings were correct, the implications could be catastrophic. Surely you had an obligation to say something. On the other hand, if your data was wrong, you could create a global panic over nothing. Since no one else had as yet published anything remotely similar, you would also have to withstand potentially withering reviews from other scientists who would scurry to refute or corroborate your conclusions. In addition, you could risk losing your funding, which was already difficult to come by.

You decided not to report your findings.

For three more years the data continued to repeat itself, however, and you could finally question the implications no longer. Your report appeared in the May 16, 1985 edition of *Nature* magazine, where you described a **40% decrease** of stratospheric ozone over Antarctica **in one month.** In speculating as to the cause of such a drastic decline, you discussed the possibility that chlorofluorocarbons (CFC's) in the atmosphere might have something to do with it.

A swift and angry response from a collection of British chemical companies resulted in the loss of funding that would have allowed your team to expand its study.

IN YOUR REPORT AT SNOWMASS, YOU SHOULD:

1. Share your findings and their potential implications.

2. Make a graph for display that contrasts Molina's predictions of ozone loss with your observations of Antarctica's ozone loss.

3. Explain what a "rate" and a "reaction rate" are.

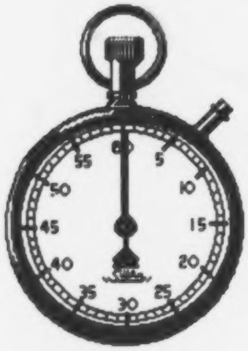
4. Pose the question to your audience, Why is the process slow in theory, but extraordinarily rapid in Antarctica?

*** It is not necessary to discuss all the information presented here. Just answer the questions well, using your own words.***

In 1973, Sherry Rowland and Mario Molina had developed a theory predicting the loss of Stratospheric ozone. Their theory implicates chlorofluorocarbons (CFC's). According to the Rowland-Molina theory, however, it takes years to break down ozone. In 1974, Mario Molina predicted a 5-7% ozone loss by 1995. In Antarctica, by contrast, ozone disappeared 40% in just one month.

You concur with the Rowland-Molina theory that outlines a series of chemical reactions resulting in ozone destruction. The **rate of reaction** is clearly more rapid in Antarctica, however, than it is according to theory. A reaction rate has to do with how fast a reaction takes place. (See text, "Rates of Chemical Reactions, below"). Why is the process so much more rapid in Antarctica than it is in theory?

The Rate Of A Reaction



The rate of a chemical reaction can be found by measuring the change in amount of reactant(s) or product(s) over a given time period.

Introduction

The rate of speed of an automobile describes how many miles it can go in an hour, or miles per hour (mph), or how fast and automobile is moving; your reading rate describes how many words you can read in a minute, or how fast you can read. Likewise, the rate of a chemical reaction describes how fast the reaction takes place, or how much of the reactants are used up in a given period of time.

Rates of Chemical Reactions

Chemical reaction rates can be measured. The rate of a chemical reaction can be found by measuring the change in amount of reactant(s) or product(s) over a given time period. The average rate of any chemical reaction may be determined by using either one of these two equations:

Reaction rates can be graphed. Time is placed on the horizontal, or x-axis. As the reader's eye moves from left to right, the graph shows what happens to the reaction rate as time goes on. The amount of product (or reactant) is placed on the vertical, or y-axis.

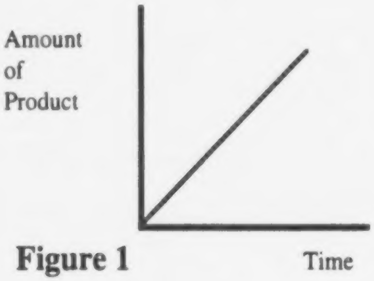


Figure 1

A reaction that occurs at a constant rate (one speed, without slowing down or speeding up) would have a graph that looks like Figure 1. A straight line on the graph indicates a constant reaction rate.

$$\text{reaction rate} = \frac{\text{amount of product formed}}{\text{time interval}} \quad \text{or} \quad \text{reaction rate} = -\frac{\text{amount of reactant used}}{\text{time interval}}$$

(the negative sign is used to show that the reactant is disappearing)

A reaction that began at a constant rate and then slowed down would have a graph that looks like either Figure 2 or Figure 3.

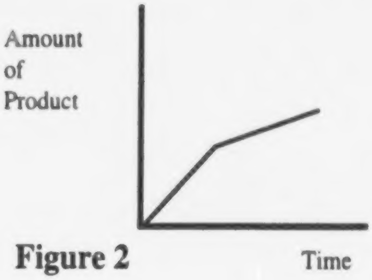


Figure 2

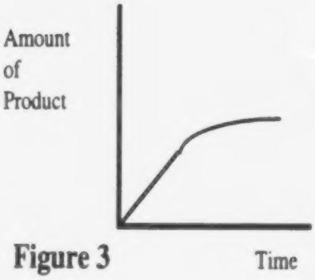


Figure 3

The difference between Figure 2 and Figure 3 depends on how the reaction slowed down. In Figure 2, the reaction instantly changed to a different, slower, but still constant rate. In Figure 3, the reaction rate slowed by changing to rates that progressively got slower and slower.

A reaction that began at a constant rate and then speeded up would have a graph that looks like either Figure 4 or Figure 5.

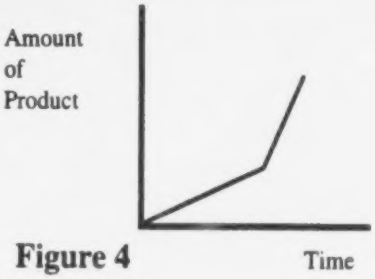


Figure 4

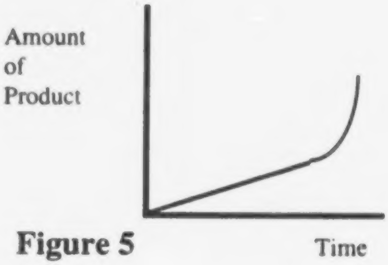
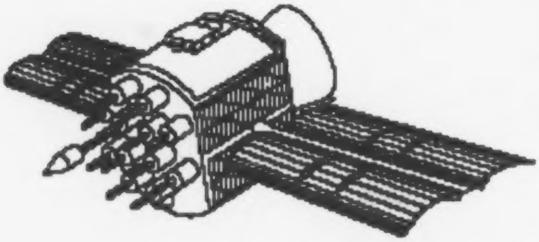


Figure 5

Again, the difference between Figure 4 and Figure 5 depends on how the reaction slowed down. In Figure 4, the reaction instantly changed to a different, faster, constant rate. In Figure 5, the reaction speeded by changing into different rates that progressively got faster and faster.

Don Heath

Your home-away-from-home is the NASA Goddard Space Flight Center in Greenbelt, Maryland, where you monitor the data you receive from the Nimbus-7 satellite. On board that satellite, floating silently above the planet, is the Nimbus-7 Total Ozone Mapping Spectrometer (TOMS). The TOMS instrument measures the amount of ozone present, digitizes what it records, and radios the information back to a high-speed computer down on planet earth.



In 1985, as far as you could tell, all ozone levels in Antarctica were well within normal. It was with great shock and alarm, then, that you read Joe Farman's paper describing an ozone "hole" there. (See **Joe Farman** description) *How could the data you were receiving be so drastically different from his?*

You called your group together for an emergency meeting. Was there an error somewhere in NASA's data collection system? If so, you had better figure out what it was, and fast. After pouring over mountains of computer printouts you finally solved the mystery.

There was nothing wrong with the Nimbus-7 satellite, or the TOMS instrument. The computer receiving the information, however, had been programmed to ignore data reporting extremely low concentrations of ozone, with the presumption that such low figures would have to indicate an error of some kind.

In order to focus on expected ozone ranges, you had instructed the computers to reject any reading below 180 Dobson Units. (A Dobson Unit is a measure of ozone concentration, and there had been no "normal" readings as low as 200 at that time.) But Joe Farman's team had been recording readings around 140 Dobson Units.

NASA's spectrometer had been faithfully recording the deepening ozone hole for several years, and sending that data back to the computer. And the computer had been doggedly discarding the information, interpreting it as being obviously erroneous.

As soon as you identified the problem, you hurriedly reprocessed the data, incorporating the previously rejected information. When the results were translated into color-coded computer graphics, not only was the ozone hole unmistakably displayed, but it was bigger than the United States in size, and it was wider and deeper than anyone had imagined.

You put together a slide show that portrayed the yearly deepening of the ozone hole, and you showed them at scientific conferences. Your satellite data was now in agreement with Joe

IN YOUR REPORT AT SNOWMASS YOU SHOULD:

1. Display and interpret the color transparencies of your Antarctic satellite data.
2. Report your satellite data on world-wide ozone loss and compare it with what was predicted. (See **Joe Farman** description.)
3. Discuss the effects of ozone depletion.
4. Ask your audience: Could the process occurring in Antarctica happen over mid-latitudes? Over the Arctic? What are the implications?

*** It is not necessary to discuss all the information presented here. Just answer the questions well, using your own words.***

Farman's findings. The existence of the hole had been confirmed.

The questions that now needed to be answered were: If ozone loss could be so rapid in Antarctica, could it happen over the mid-latitudes? Was it already happening over the Arctic, where (unlike Antarctica) human populations exist below? The answers to these questions were critical, because they could impact the entire world. The potential effects of ozone depletion are serious. (See text, "Impacts of Ozone Depletion")

In 1987, you concluded by analyzing your satellite data that there had apparently been a world-wide 4 percent drop in total ozone. You reported your conclusion with the understanding that this was not an indisputable piece of information. Possible sources of error included the fact that the instruments could be out of calibration. The following year, however, your measurements were examined in comparison with ground-based readings from around the world. The four percent figure was not only confirmed, but revised upwards— to a probable 6 percent total ozone loss.

BEST COPY AVAILABLE

Health Risks of Over-exposure to the Sun[1]

Most people are now aware that too much sun has been linked to skin cancer, but few know the degree of risk posed by overexposure, and fewer are aware that the risks go beyond skin cancer. Recent medical research has shown that overexposure to the sun's ultraviolet (UV) radiation can contribute to serious health problems.

This fact sheet provides a quick overview of the major problems linked to UV exposure: skin cancer (melanoma and non-melanoma), other skin problems, cataracts, and immune system suppression. Understanding these risks and taking a few sensible precautions will help you to enjoy the sun while lowering your chances of sun-related health problems later in life.

Melanoma

Melanoma, the most serious form of skin cancer, is also one of the fastest growing types of cancer in the U.S. Many dermatologists believe there may be a link between childhood sunburns and malignant melanoma later in life. Melanoma cases in the U.S. have almost doubled in the past two decades, with at least 32,000 new cases and 6,900 deaths estimated for 1994 alone. The rise in melanoma cases and deaths in America is expected to continue.

Non-Melanoma Skin Cancers

Unlike melanoma, non-melanoma skin cancers are rarely fatal. Nevertheless, they should not be taken lightly. Untreated, they can spread, causing more serious health problems. An estimated 900,000 Americans developed non-melanoma skin cancers in 1994, while 1,200 died from the disease.

Actinic Keratoses

These sun-induced skin growths occur on body areas exposed to the sun. The face, hands, forearms, and the "V" of the neck are especially susceptible to this type of blemish. They are pre-malignant, but if left untreated, actinic keratoses can become malignant. Look for raised, reddish, rough-textured growths.

1.Reference

Environmental Protection Agency. Health Effects of overexposure to the sun. [Online] Available http://www.epa.gov/ozone/uvindex/uvhealth.html, March 5, 1996.

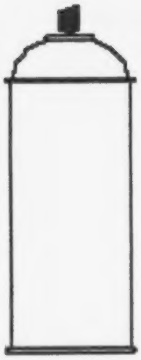
Cataracts and Other Eye Damage

Cataracts are a form of eye damage, a loss of transparency in the lens which clouds vision. Left untreated, cataracts can rob people of vision. Research has shown that UV radiation increases the likelihood of certain cataracts. Although curable with modern eye surgery, cataracts diminish the eyesight of millions of Americans, and necessitate millions of dollars of eye surgery each year. Other kinds of eye damage include: pterygium (tissue growth on the white of the eye that can block vision), skin cancer around the eyes, and degeneration of the macula (the part of the retina near the center, where visual perception is most acute). All of these problems could be lessened with proper eye protection from UV radiation.

Immune Suppression

Scientists have found that sunburn can alter the distribution and function of disease-fighting white blood cells in humans for up to 24 hours after exposure to the sun. Repeated exposure to UV radiation may cause more long-lasting damage to the body's immune system. Mild sunburns can directly suppress the immune functions of human skin where the sunburn occurred, even in people with dark skin.

Sherwood "Sherry" Rowland



CFC's were banned in the US from use in aurosol sprays in 1987.

You are a large man, with feet to match. You have a pleasant, calm personality, and a sonorous voice. You tend to peer over your half-glasses from time to time, and fix your audience with a professorial gaze. You know your stuff.

You and Mario Molina, your postdoctoral student, had been seeking to answer what you had originally thought was a fairly simple question: "Where do chlorofluorocarbons (CFC's) go when they escape at ground level?

The most well known CFC's are marketed by DuPont under the trade name of Freon®. It takes a lot to get them to change into something else, and as such are extremely useful. CFC's are not very volatile (they have a low boiling point), they are insoluble in water, and they are highly stable, i.e. they are extremely unreactive. Such a brilliant design makes them ideal for such things as refrigerants, propellants and solvents, and their indestructibility, so it was thought, would make them harmless to the environment. But where do they go once they are released?

The rate of a chemical reaction depends in part on the nature of the reactants. (See "Nature of Reactants" text). Stable molecules react slowly. Unstable molecules react rapidly. You and Molina determined that CFC's are so stable, they don't react with anything at all in the Troposphere. They just keep floating upwards until they float past the ozone layer, that thin blue band of gas that shields the earth from ultraviolet radiation. Once in the stratosphere, the CFC's begin at long last to break up as their bonds are exposed to ultraviolet rays.

$$CCl_2F_2(g) \xrightarrow{\upsilon\nu} CClF_2(g) + Cl(g)$$

One of the survivors of this photodissociation is the tiny little chlorine atom (Cl) floating around all by itself. Chlorine is extremely unstable, and is therefore highly reactive. As soon as it meets up with ozone (O_3), (ozone is also an unstable molecule) the Cl steals away one of the oxygen atoms, and becomes ClO, while ozone, robbed of one of its oxygen atoms, becomes a stable oxygen molecule (O_2).

ClO, like Cl, is also highly unstable. It encounters a free oxygen atom (O), forming O2 and Cl. Now the chlorine atom is once again free to go destroy another ozone molecule. This cycle continues over and over. According to your theory, a single chlorine atom can attack and destroy several thousand ozone molecules.

When Mario Molina presented you with the unlikely theory that CFC's were destroying the ozone layer, the two of you figured there *must* be some kind of mistake in the data. You went over and over the figures, but could find no errors. You wrote up the results, and *Nature* Magazine presented the "Rowland-Molina Theory" in their June 28, 1974 issue.

IN YOUR REPORT AT SNOWMASS YOU SHOULD:

1. Create a visual display outlining the series of chemical reactions put forth by the Rowland-Molina Theory.
2. Explain the Rowland-Molina Theory.
3. Explain how the nature of the reactants (whether the reactants are reactive or stable) can affect the rate of a reaction, using examples from the scenario you have described.
4. Ask your audience: "How long would it take for this process to take place? What eventually happens to the chlorine atom? What would prevent it from continuing to destroy ozone until the ozone is completely gone?

*** It is not necessary to discuss all the information presented here. Just answer the questions well, using your own words.***

Concerned about the serious global implications of your theory, you brought the matter into the public arena, willingly interacting with the press, politicians, and the public. Your decision to take such a visible stance earned you black marks in industrial and academic circles. Over the next ten years, you were suspiciously regarded as an advocate, rather than as an objective scientist. No industry groups invited you to speak, and rarely was your presence requested at other universities, despite your prestigious accomplishments.

With the discovery of the ozone hole in Antarctica, however, the empirical "proof" of your theory began to emerge. As time wore on, your stance was more than vindicated, and you became a sought after figure in the lecture circuit.

Collision theory describes the model that is used to explain the rates of chemical reactions. According to this theory, rates of chemical reactions depend on collisions between reacting particles. Any change that affects the

A Theory to Explain Reaction Rates

Collision theory describes the model that is used to explain the rates of chemical reactions. According to this theory, rates of chemical reactions depend on collisions between reacting particles. Any change that affects the collisions will also affect the rate of reaction.

Factors that Influence Reaction Rates

Several different factors play an important role in influencing reaction rates. Sometimes one of these factors acts alone and sometimes several factors act at the same time.

Nature of Reactants

Sometimes the rate of a reaction is influenced directly by the nature of the specific reactants that are involved. Consider two metals, potassium and calcium. The reaction of potassium and water is much quicker and more intense than the reaction of calcium and water. The difference in reaction rates is because of differences in the nature (or makeup) of the reactants. An increase in temperature or concentration would not change the rate in a significant way, because the very nature of the two metals is the most important reason to explain the difference in reaction rates.

The reaction of calcium in cold water is slower than the reaction of potassium in cold water. If the water for the calcium reaction is heated, the calcium reaction will occur somewhat faster, but will still be significantly slower than the potassium reaction in cold water. Because calcium and potassium, by their very nature, react at different rates in water (the potassium reaction is sudden and intense, while the calcium reaction is slow), increasing the temperature or concentration will not have a major effect on the relative reaction rates of these two metals.

Mario Molina

You are the son of the Mexican ambassador to the Philippines. Your closely cropped beard and short stature are complemented by a quiet voice, intense eyes, black hair, and a kindly appearance.

You and Sherry Rowland are collaborators and intellectual soul-mates. Although it was Rowland who wrote and published the paper on the "Rowland-Molina Theory", it was you who performed the initial calculations which brought you to the conclusion that chlorofluorocarbons are destroying the ozone layer. (See **Sherwood "Sherry" Rowland** description.)

One of the most alarming aspects of your theory was that, according to your calculations, almost all of the chlorofluorocarbons that had ever been released into the lower atmosphere were still *in* the lower atmosphere, and going up. Because it takes decades for all of the CFC-borne chlorine atoms to reach the stratosphere, the ability of CFC's to destroy the ozone layer would be unstoppable for forty or fifty years *even if all CFC production was immediately halted worldwide!*

When you and Rowland testify to Congress in 1974, recommending that CFC production be halted, the chemical industry (led by DuPont) responded by funding research projects designed to disprove the Rowland-Molina theory. Over eight billion dollars of revenue from the manufacture and sale of CFC's and related products would be affected by such a proposition. Should so many jobs and consumer products be threatened without more proof? On the other side, environmentalists responded: Can we afford to wait for more proof and gamble with the Earth's welfare?

While the controversy raged around you, and scientists tried to assess the validity of your theory, you continued to study the problem. What might prevent chlorine atoms released from CFC's into the stratosphere from destroying so many ozone molecules? And where would those chlorine atoms finally come to rest?

The rate of a chemical reaction depends in part on the nature of the reactants. Stable molecules react slowly. Unstable molecules react rapidly. You were looking for a chemical "sink". When an unstable molecule attaches itself to a molecule or molecules to form a stable compound, the result is a chemical sink. If the highly unstable chlorine atom were to become part of a stable compound, this would prevent any further chemical reactions from occurring.

IN YOUR REPORT AT SNOWMASS YOU SHOULD:

1. Explain chlorine nitrate as a chemical sink for chlorine, and the relationship of a chemical "sink" to reaction rates.
2. Discuss the pros and cons of an immediate ban on CFC's and chlorine containing substitutes. Elicit opinions from your audience.

*** It is not necessary to present all the information presented here. Just answer the questions well, using your own words.***

In 1976, you found such a sink in chlorine nitrate ($ClONO_2$). Chlorine nitrate is formed when chlorine monoxide reacts with nitrogen dioxide. Nitrogen dioxide occurs naturally in the stratosphere in small amounts.

At first you hadn't paid much attention to chlorine nitrate, thinking its lifetime would be too short to limit the chlorine's destructive attraction to ozone, but after pouring over some obscure chemical abstracts written in German you began to consider otherwise. With a series of lab experiments you confirmed your new hypothesis that the chlorine nitrate compound was stable enough to hold significantly large numbers of chlorine atoms.

$$ClO(g) + NO_2(g) \longrightarrow ClONO_2(g)$$

Although you were aware that your conclusions might blow your original theory out of the water, being the highly professional, objective scientist that you were, you dutifully reported your findings. Industry responded by spreading the word that the Rowland-Molina theory had been disproved. Scientists rushed back to their labs, slaving over computers and calculators to rework their conclusions. And policy makers furrowed their brows and scratched their heads in confusion, trying to decide how to- or whether to- act on the data given.

The Rowland-Molina Theory hadn't been disproved. It had only been revised. Within a few months, scientists concluded that the chlorine nitrate sink would have a mild effect on projected predictions of ozone loss.

In September of 1987, the Montreal Protocol was signed, where the world's nations agreed to phase out CFC production. Today, 150 countries have signed the treaty. Beginning January 1, 1996, only recycled and stockpiled CFCs are available for use in industrialized countries.

Bob Watson

You have a scraggly beard and wild, undisciplined black hair. You are an enthusiastic and energetic public speaker with a British accent. You are also the head of NASA's Stratospheric Research programs, and a highly respected scientist.

It came to be your responsibility to marshal the forces that would answer the pivotal questions; "What caused the ozone hole in Antarctica?" and "Was it natural or man-made?"

Once the ozone hole was detected and confirmed, several competing theories developed in an attempt to answer those questions. One theory attributed the loss of ozone to sunspots and flares. Another theory held that changing patterns of air circulation around the South Pole were transporting ozone-poor air into the region and giving the false appearance of ozone loss. Both these theories pointed to *natural* causes for the hole.

Only one theory, the theory that ozone loss stemmed from chemical reactions involving chlorine, indicated *man-made* sources, and implicated CFC's as the culprit.

You organized a land-based expedition to Antarctica in 1986, and an airborne expedition in 1987, in search of hard evidence. The challenge was to get the actual observations with sufficient quality so that no one could seriously question the raw findings. Your expedition planning sessions resembled a war room before a major military assault. You brought together some of the country's brightest minds and you spared no expense in an attempt to solve this scientific problem that potentially threatened mankind.

You knew that if the hole was natural, the scientific community might look a little silly for launching such a frenetic campaign. If it was man-made, on the other hand, it could be a threat to its makers. The stakes were high, and you couldn't afford to make mistakes.

The timing for each expedition had to be in the Spring, which in the Southern hemisphere begins in September. This is when the sun begins to rise in Antarctica, after months of darkness. One month later, the ozone hole makes its yearly appearance. According to the "chemical" theory for the ozone hole, chlorine atoms were locked up in the darkness in stable, unreactive molecules. When the sun rose each September, ultraviolet radiation broke the bonds holding the chlorine atoms captive, and freed them to react with other molecules.

In addition, the rate of a chemical reaction increases as temperature increases. (See "Temperature" text). The free chlorine atoms would grow increasingly excited with the rising sun, speeding up their molecular dance, and increasing the rate at which they collide into, react with, and destroy ozone.

IN YOUR REPORT AT SNOWMASS YOU SHOULD:

1. Outline the competing theories regarding the cause of the Antarctic ozone hole and the implications of each.
2. Discuss the effects of temperature and concentration on reaction rates, and the relationship of each to answering the question of what caused the Antarctic ozone hole.
3. Ask your audience: Do you think the Antarctic ozone hole is natural or man-made? Why?

*** It is not necessary to present all the information presented here. Just answer the questions well, using your own words.***

The concentration of the reactants also affects the rate of reaction, however. (See "Concentration" text). Rates of reaction in the gas phase must take place slowly, because molecules are far apart. In the liquid phase, on the other hand, reactions are much more rapid, because the molecules are already rubbing against each other and don't require random collisions to react. The difference between the two is as great as comparing the number of possible automobile accidents on a lonely country road to those that might occur during downtown rush hour. According to observations, molecules were reacting as fast as cars might collide in a snarled traffic jam. The Stratosphere is in a gaseous state, however; the collisions should have been occurring at a much more leisurely rate, since gas molecules are few and far between. What could the reason be for such a discrepancy?

The teams that you sent down to the frigid South would be measuring levels of ClO in the atmosphere. High levels of ClO would tend to validate the "chemical" theory for the ozone hole, and point to destruction from man-made sources. No matter how energetic a sun dance the chlorine did when sunlight returned to the Antarctic sky, however, it couldn't possibly gobble ozone at the observed rates because of temperature increases alone. Another part of the chemical theory, developed by **Susan Solomon** and others, would serve to explain the extraordinarily rapid rate of ozone destruction.

A Theory to Explain Reaction Rates

Collision theory describes the model that is used to explain the rates of chemical reactions. According to this theory, rates of chemical reactions depend on collisions between reacting particles. Any change that affects the collisions will also affect the rate of reaction.

Factors that Influence Reaction Rates

Several different factors play an important role in influencing reaction rates. Sometimes one of these factors acts alone and sometimes several factors act at the same time.

Concentration

An increase in concentration will cause an increase in reaction rate because there will be more reactant molecules available for collisions.

Think back again to the earlier reaction with magnesium and hydrochloric acid.

$$Mg(s) + 2HCl(aq) \longrightarrow H_2(g) + MgCl_2(aq)$$

As we just saw with surface area, one way to speed up the reaction is to cut the magnesium into very small pieces so that there is greater magnesium surface area. Greater surface area allows a faster rate of reaction.

Another method to increase the reaction rate of this reaction is to increase the concentration of the hydrochloric acid. As the hydrochloric acid becomes more concentrated in the same volume, it becomes more "crowded". There are more reactant molecules so it becomes easier for collisions to take place. The reaction rate will increase. This phenomena applies to more than just this magnesium-hydrochloric acid reaction; the statement applies to most reactions. So, two methods to increase reaction rates are to increase surface area and to increase the concentration of the reactants.

Temperature

It takes more than just a collision between molecules for a reaction to take place. The collision must have enough energy so that a reaction can occur. Since an increase in temperature will increase the energy in a molecule, the result is that more collisions can lead to reactions, because the overall energy level of the heated molecules is higher. Let's look closer.

Raising the temperature of a solution increases the average velocity and kinetic energy (energy of motion) of the molecules and increase the rate of a reaction. For many reactions that occur near room temperature, an increase in temperature by 10 degrees Celsius will double the rate of reaction.

You are a tall, easy-going scientist with prematurely white hair and a broad, weathered face. At the National Sci-

Jim Anderson

entific Balloon facility, you had been hard at work looking for the atmospheric evidence that would prove the Rowland-Molina theory to be true—or false. (See **Sherwood "Sherry" Rowland** description)

It had already been proven that CFC's were reaching the Stratosphere without coming apart or changing form in the Troposphere. It had also been established that once in the Stratosphere, CFC's disassociate and release chlorine molecules when they are struck by ultraviolet light.

The final missing piece—the last unsolved mystery—was the search for the chemical "smoking gun": ClO, or chlorine monoxide. Chlorine monoxide could only exist in the Stratosphere as a result of ozone destruction. If ClO wasn't there, then Rowland and Molina were wrong.

Your mission was not a simple one. What you were looking for was evidence of a molecule scattered in the atmosphere at concentrations of no more than two parts per billion. Your instruments were thirty-five thousand pound packages of lasers and electronics controlled by computers and launched in eight hundred foot-long balloons. In 1977, you found the telltale ClO.

The Rowland-Molina Theory can be summarized as follows:

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O \longrightarrow Cl + O_2$$

Acting as a self-appointed atmospheric Robin Hood, chlorine steals an oxygen atom away from an ozone molecule. It then donates the oxygen atom back to another oxygen atom to form O_2 gas. The chlorine atom briefly turns into ClO, and then reverts back to Cl; in the end, chlorine remains unaffected.

The net result of this activity is the destruction of ozone:

$$O_3 + O \longrightarrow O_2 + O_2$$

Ozone is breaking down and reforming all the time in the atmosphere, but chlorine speeds up the breaking down part of the cycle. In this process, chlorine acts as a catalyst—a substance that speeds up the rate of a reaction while the substance itself remains unchanged. (See "Catalysts" text)

In 1986, Bob Watson asked if you could redesign your equipment so that it could be attached to an aircraft flying above sixty thousand feet in Antarctic temperatures as low as -120° F. (See **Bob Watson** description) The purpose: to verify the cause of the ozone hole. You cut your vacation short and got right to work.

Over *ten million dollars* of research money went into preparing for ten

IN YOUR REPORT AT SNOWMASS, YOU SHOULD:

1. Explain what a catalyst is, chemically speaking.
2. Explain the catalytic nature of the destruction of ozone by chlorine.
3. Facilitate a discussion with your audience: Does the data that you collected prove that CFC's caused the ozone destruction in Antarctica? Why or why not?

*** It is not necessary to present all the information presented here. Just answer the questions well, using your own words.***

flights of the ER-2, a modified version of the Lockheed U-2 spy plane. You couldn't afford to fail. On the first flight, however, one of your worst nightmares came true. As the plane flew towards Antarctica, the temperature dropped, and something opened up in one of the circuits or connectors or wires.

You had less than 16 hours before the next flight out, to solve the problem. Staying up all night, you and your team wrote a computer diagnostic program designed to test the circuits one by one if the instrument failed again, thereby recording which one of the connectors was opening. On the second flight, the instrument failed again, but the diagnostic worked. When the plane came back from its mission, you were able to identify and fix the faulty wiring.

The morning of the third flight you held your breath as you watched the plane take off once again from Puntas Arenas, Chile, headed for Antarctica. This was the make-or-break attempt. You couldn't keep sending out pilots day after day with equipment that didn't work.

That evening you dumped the data from the returning plane into a computer. The instrument had worked, and the data was significant. Your equipment recorded ClO concentrations five hundred times higher than readings taken elsewhere on the planet. Notably, as the concentration of ClO went up, the concentration of ozone went down.

By the end of the expedition, your team concluded that: 1) The ozone hole had reappeared and was even deeper than the year before. 2) More than half the ozone had been destroyed over an area of roughly 12.5 million square miles, and 3) chlorine was the cause.

Factors that Influence Reaction Rates

Several different factors play an important role in influencing reaction rates. Sometimes one of these factors acts alone and sometimes several factors act at the same time.

Catalysts

A **catalyst** is a substance that makes a reaction go faster without itself being "used up" in the reaction. A catalyst is different from a reactant because the amount of catalyst will be the same before and after the reaction.

For example, hydrogen peroxide (H_2O_2) breaks down into water and oxygen gas. The equation for this reaction is:

$$2H_2O_2(aq) \longrightarrow 2H_2O\,(l) + O_2(g)$$

This reaction occurs very slowly. (This is one reason why a bottle of hydrogen peroxide that is purchased for use as a disinfectant will last for one year or so, before it becomes inactive. The other reason is that inhibitors are added to minimize the reaction and prolong shelf life.) If manganese dioxide (MnO_2) is added to hydrogen peroxide, the decomposition reaction will occur very quickly. The manganese dioxide acts as a catalyst, and allows the hydrogen peroxide to breakdown rapidly. (Another interesting catalyst that would increase the rate of this reaction is the addition of chopped liver!) The equation with the catalyst present would be written like this:

$$2H_2O_2(aq) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$$

This notation shows that the MnO_2 is present as a catalyst, but does not enter directly into the reaction.

Catalysts can be homogeneous or heterogeneous. A **homogeneous catalyst** exists in the same phase as the reactants. A homogeneous catalyst enters into the reaction, but is returned, unchanged, in the final step of the reaction. Typically, homogenous catalysts form intermediate compounds that react more easily and readily than the reactants without the catalyst.

Heterogeneous catalysts are catalysts that are in a phase that is different than the phase the reactants are in. Often, the catalyst is a solid, and the reactants are liquid. The catalyst provides a surface for the liquid molecules to react on. It is easier for the reaction to occur on the surface of the catalyst, than if the liquids were left to react together, without the presence of the catalyst.

Another group of catalysts are **enzymes**. Enzymes are biological catalysts that increase the reaction rate for biological processes.

Susan Solomon

While still a chemistry student at the Illinois Institute of Technology, you became hooked on atmospheric chemistry, and you became fascinated with using computer modeling to investigate changes in the atmosphere. But you never dreamed that your chosen career path would send you to the frozen wasteland of the coldest place on earth.

The odyssey began when you were asked to review Joe Farman's article for publication in *Nature* Magazine. (See **Joe Farman** description) You became heavily involved in trying to answer the question, "Why was the ozone depletion in Antarctica occurring so much more rapidly than elsewhere on the planet?" Gradually, you started to develop a theory. You published some of your ideas in *Nature* Magazine, June 19, 1986.

You were becoming increasingly convinced that a key to the answer involved the Polar Stratospheric Clouds (PSC's), formations of ice crystals and frozen nitric acid found for the most part only in Antartica, where temperatures can fall below -80° C. These tiny frozen particles hang some fifteen to twenty kilometers above Antarctica—exactly the same altitude the winter Antarctic ozone layer.

Meanwhile, also in the very same narrow zone of the earth's atmosphere, UV bombarded CFC's were releasing free chlorine into the Stratosphere. Much of this chlorine would get locked safely away in stable, gaseous chlorine nitrate ($ClONO_2$) or hydrogen chloride (HCl) molecules. (See **Mario Molina** description)

Ordinarily, chlorine nitrate gas and hydrogen chloride gas do not react with each other in the atmosphere. In Antarctica, however, you theorize that PSC's play the role of a catalyst (See "Catalysts" text) The PSC's could provide a surface on which the molecules of $ClONO_2$ and HCl would be able to react, in which case the following reaction would take place:

$$ClONO_2(g) + HCl(g) \xrightarrow{PSC's} Cl_2(g) + HNO_3(s)$$

As a result of the reaction, the chlorine is released from the stable molecular "sinks", and forms the more vulnerable $Cl_{2(g)}$. When the sun begins to return in September after a dark Antarctic winter, ultraviolet radiation breaks the bonds of Cl_2 and an army of free Cl radicals suddenly begin destroying the ozone.

The PSC's are tiny and abundant. Therefore they have a great deal of exposed surface area. The amount of available surface area affects the rate of the reaction. (See "Surface Area" text) If PSC's were to exist in the form of a few large chunks of ice, for example, the amount of exposed surface area would be less and the rate of the reaction would be slower.

But all of this was only a theory

IN YOUR REPORT AT SNOWMASS, YOU SHOULD:

1. Explain how a catalyst can increase the rate of a chemical reaction.
2. Explain how the amount of exposed surface area can increase the rate of a chemical reaction.
3. Explain why ozone depletion occurs so much more rapidly in Antarctica than elsewhere on the planet.
4. Facilitate a discussion with your audience: Could what happened in Antarctica potentially happen somewhere else? Why or why not?

*** It is not necessary to present all the information presented here. Just answer the questions well, using your own words.***

until it could be proved with some hard, solid data. And you were the one who volunteered to lead the expedition to Antarctica to collect it.

You and your team of scientists set up camp at McMurdo Sound air force base in the dead of the Polar winter, August of 1986. You cut a hole in the roof so that moonlight could reach the Atmospheric Trace Molecule Spectrometer, which needed to be kept at room temperature. You and the members of your team had to take turns sitting outside on the frozen roof in 20 minute shifts, holding a mirror that would guide moonbeams down the hole. When the beams of light hit the spectrometer, the instrument would break it into a spectrum of dark and light bands, which could be analyzed by a computer for the presence of certain molecules. You were looking for chlorine dioxide (OClO), the appearance of which would indicate that the chlorine molecule was the ozone destroying culprit.

The data you collected, at the expense of numbingly cold fingers and toes, supported the chemical theory for ozone depletion. It appeared that the ozone hole was indeed a man-made, not a natural phenomenon.

Factors that Influence Reaction Rates

Assume you are to generate hydrogen gas from magnesium and hydrochloric acid. Assume that you have more than enough hydrochloric acid. Which form of reactant would you use so that the reaction goes as fast as possible?

One 25-gram piece of magnesium?

or

Twenty-five 1-gram pieces of magnesium?

Several different factors play an important role in influencing reaction rates. Sometimes one of these factors acts alone and sometimes several factors act at the same time.

Surface Area

An increase in surface area causes a reaction to proceed faster because there is more direct contact (collisions) between reacting molecules if there is more surface area. Let's look closer at this factor.

The amount of surface area affects the rate of reaction. In the reaction given earlier, solid magnesium is exposed to hydrochloric acid to produce hydrogen gas and magnesium chloride.

$$Mg(s) + 2HCl\ (aq) \longrightarrow H_2(g) + MgCl(aq)$$

The reaction rate will increase if the amount of surface area of magnesium is increased since there are more collision sites. If the surface area is increased by cutting the magnesium into small pieces, more magnesium will be in contact with the acid, and the reaction will proceed faster.

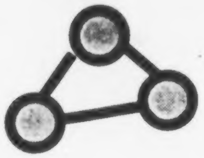
Assume you are to generate hydrogen gas from magnesium and hydrochloric acid. Assume that you have more than enough hydrochloric acid. Which form of reactant would you use so that the reaction goes as fast as possible? One 25-gram piece of magnesium? or Twenty-five 1-gram pieces of magnesium?

Using smaller pieces of magnesium will give a faster reaction rate than using a single, larger piece. Considering the two choices for magnesium, do you think the amount of hydrogen gas produced is the same?

Yes, it will be. In each case, the amount of magnesium that will react with the acid is the same. (It is only the form of the magnesium, large or small pieces, that is different.) In each case the amount of hydrogen gas that is produced is the same. When many small pieces of magnesium are used, the time it takes to react all of the magnesium with the acid will be shorter than if one larger piece of magnesium is used.

Another common example of a chemical reaction is oxidation of iron, known as rusting. Rusting of an iron bar will occur slower than rusting of an equal amount of iron filings (or shavings). The filings have more surface area exposed to air, so the reaction can proceed faster.

Analysis Of Ozone Depletion Data



Name: ______________________________

Date: ______________________________

Period: ______________________________

OBJECTIVES

- Analyze data.
- Describe the formation and destruction of ozone
- Compare and contrast ozone data

Examine the graphs and graphics located in the "ozone graphics" file on your computer, and answer the questions below. All of the graphs and the questions have to do with stratospheric ozone depletion.

I. Graphics

A. Location makes a difference

1. What effect does ozone have when it is located in the stratosphere?

2. What effect does ozone have when it is located in the troposphere?

B. Model of ozone cycle

1. Write the series of equations for the natural production of ozone in the stratosphere. (Each line of the diagram represents a different equation.)

2. Write the series of equations for the "Chapman Process" for the destruction of ozone in the stratosphere.

II. Continental

A. Continental ozone levels

1. Examine the three images in the "Continental-Ozone-Levels" folder. In general, do ozone levels tend to be greater towards the equator or towards the poles? (Click on the scoll down bar to reveal the color-coded key. A Dobson Unit is a measure of ozone concentration. The greater the Dobson unit, the more ozone there is in the atmosphere in that location. Five hundred Dobson units indicates a high presence of ozone. Two hundred Dobson units indicates a low presence of ozone.)

B. 1926-93 Ozone levels over Arosa, Switzerland.

This graph represents ozone measurements taken from the ground in Arosa, Switzerland, and compares that data to measurements taken form a satellite called TOMS.

1. Notice how the ozone levels fluctuate. What is the highest number of Dobson units reached, and in what year does that reading occur?

2. What is the lowest number of Dobson units reached, and in what year does that reading occur?

3. Is there a significant downward trend of ozone levels in Arosa?

C. 1964-93 Ozone Levels in Tallahassee, Florida

1. How often does ozone reach a peak concentration and then go down again?

2. What might the up and down cycling of ozone concentrations have to do with?

3. Is there a significant downward trend of ozone levels over Tallahassee?

4. Compare the average peak ozone levels over Tallahassee, Florida, to those over Arosa, Switzerland.

5. What ideas do you have to explain the differences between the ozone levels on the two graphs of Arosa and Tallahasee? (Check out the location of the two cities on the world map.)

III. Antarctica

A. September 1995 Antarctica

1. Is there evidence in this image for an ozone "hole" in Antarctica? Why, or why not?

2. In what area is the concentration of ozone the greatest?

B. Antarctica Ozone Hole Size

1. In what year did the size of the ozone hole equal the area of the continent of Antarctica?

2. Has size of the ozone hole ever gotten as large as the area of the continent of North America?

3. When was the last time that the recorded size of the ozone hole was smaller than the year before?

4. What does this graph measure?

5. Overall, is the ozone hole getting smaller each year?

C. Antarctica Spring Ozone Minima

1. Both this graph and the Antarctica Ozone Hole Size graph are measuring something about the ozone hole in Antarctica, but they are not measuring the same thing. What does this graph measure? Refer to your answer to question B4. How are the measurements different? Contrast the two graphs, and explain what the different measurements are.

2. In what year did the concentration of ozone reach the lowest?

3. Is the yearly minimum level of ozone above Antarctica from 1978-1994 increasing, decreasing, or staying about the same?

4. In what month of the year is the concentration of ozone most likely to reach its minimum level?

D. September 1991-92 Antarctica

1. The scales refer to concentration of ClO (on the left) and ozone (on the right). The white hole over the south pole indicates a lack of data in that area. (In other words, ignore the white space.) Is there a relationship between the gas ClO and ozone in the atmosphere? If so, what is that relationship? If not, why do you say there isn't?

IV. Arctic Ozone Levels

1. In your opinion, is there or is there not a growing ozone "hole" in the Northern Hemisphere? Why or why not?

Analysis Of Ozone Depletion Data

TEACHER BACKGROUND

OBJECTIVES

Students will

- Analyze data.
- Describe the formation and destruction of ozone
- Compare and contrast ozone data

SCIENCE SKILLS

- Data analysis

Preparation

The graphs and graphics in this activity can be found on the World Wide Web at the addresses indicated. You will need to

1. download the graphics
2. convert the graphics from "gif" to "pict" format
3. load the folder of graphics onto the computers at your school

Examine the graphs and graphics located in the "ozone graphics" file on your computer, and answer the questions below. All of the graphs and the questions have to do with stratospheric ozone depletion.

I. Graphics

A. Location makes a difference

(http://spso.gsfc.nasa.gov/NASA_FACTS/ozone/ozone.html)

1. What effect does ozone have when it is located in the stratosphere?

It protects us from the sun's harmful radiation.

2. What effect does ozone have when it is located in the troposphere?

It can damage lung tissue and plants.

B. Model of ozone cycle

(http://spso.gsfc.nasa.gov/NASA_FACTS/ozone/ozone.html)

1. Write the series of equations for the natural production of ozone in the stratosphere. (Each line on the diagram represents a different equation.)

$$O_2 \xrightarrow{uv} O + O$$

$$O + O_2 \longrightarrow O_3$$

2. Write the series of equations for the "Chapman Process" for the destruction of ozone in the stratosphere.

$$O_3 \xrightarrow{uv} O + O_2$$

$$O + O_3 \longrightarrow O_2 + O_2$$

II. Continental

A. Continental ozone levels

(http://ssbuv.gsfc.nasa.gov/o3imag.html and *http://nic.fb4.noaa.gov:80/products/stratosphere/tovsto/)*

1. Examine the three images in the "Continental-Ozone-Levels" folder. In general, do ozone levels tend to be greater towards the equator or towards the poles? (Click on the scoll down bar to reveal the color-coded key. A Dobson Unit is a measure of ozone concentration. The greater the Dobson unit, the more ozone there is in the atmosphere in that location. Five hundred Dobson units indicates a high presence of ozone. Two hundred Dobson units indicates a low presence of ozone.)

Ozone levels tend to be greater towards the poles. The exception to this is the man-made Antarctic ozone "hole", visible in the third image.

B. 1926-93 Ozone levels over Arosa, Switzerland. This graph represents ozone measurements taken from the ground in Arosa, Switzerland, and compares that data to measurements taken form a satellite called TOMS.

(http://jwocky.gsfc.nasa.gov/arosa.gif)

1. Notice how the ozone levels fluctuate. What is the highest number of Dobson units reached, and in what year does that reading occur?

Just over 360 Dobson Units, in 1942.

2. What is the lowest number of Dobson units reached, and in what year does that reading occur?

Less than 300 Dobson Units, in 1993.

3. Is there a significant downward trend of ozone levels over Arosa?

From 1973 to 93 there is a significant downward trend in ozone levels in Arosa.

C. 1964-93 Ozone Levels over Tallahassee, Florida

http://thunder.met.fsu.edu/~nws/gifs/tlhozo.gif

1. How often does ozone reach a peak concentration and then go down again?

Once every year.

2. What might the up and down cycling of ozone concentrations have to do with?

It probably has to do with the changes of seasons.

3. Is there a significant downward trend of ozone levels?

No.

4. Compare the average peak ozone levels over Tallahassee, Florida, to those over Arosa, Switzerland.

Average peak concentrations are higher in Arosa.

5. What ideas do you have to explain the differences between the ozone levels on the two graphs of Arosa and Tallahasee? (Check out the location of the two cities on the world map.)

Arosa is significantly farther north than Tallahassee. Ozone levels tend to be less concentrated toward the equator. Reduction of ozone levels, however, appears to be more pronounced towards the poles.

III. Antarctica

A. September 1995 Antarctica

(http://nic.fb4.noaa.gov:80/products/stratosphere/tovsto/)

1. Is there evidence in this image for an ozone "hole" in Antarctica? Why, or why not?

The concentration of ozone over Antarctica is 180 Dobson units, the lowest concentration both in the image and on the key code.

2. In what area is the concentration of ozone the greatest?

In the region immediately surrounding the ozone hole.

B. Antarctica Ozone Hole Size

(http://jwocky.gsfc.nasa.gov/o3holesz.gif)

1. In what year did the size of the ozone hole equal the area of the continent of Antarctica?

1985

2. Has size of the ozone hole ever gotten as large as the area of the continent of North America?

Almost, but not quite.

3. When was the last time that the recorded size of the ozone hole was smaller than the year before?

1988

4. What does this graph measure?

This graph measures the area of the size of the ozone hole in Antarctica.

5. Overall, is the ozone hole getting smaller each year?

No, it is getting larger.

C. Antarctica Spring Ozone Minima

(http://jwocky.gsfc.nasa.gov/o3holemin.gif)

1. Both this graph and the Antarctica Ozone Hole Size graph are measuring something about the ozone hole in Antarctica, but they are not measuring the same thing. What does this graph measure? Refer to your answer to question B4. How are the measurements different? Contrast the two graphs, and explain what the different measurements are.

The previous graph measures the largest area reached in a year, and this graph measures the lowest concentrations of ozone reached each year.

2. In what year did the concentration of ozone reach the lowest?

1993

3. Is the yearly minimum level of ozone above Antarctica from 1978-1994 getting less concentrated, more concentrated or staying about the same?

The concentrations are getting less.

4. In what month of the year is the concentration of ozone most likely to reach its minimum level?

October

D. September 1991-92 Antarctica

1. The scales refer to concentration of ClO (on the left) and ozone (on the right). The white hole over the south pole indicates a lack of data in that area. (In other words, ignore the white space.) Is there a relationship between the gas ClO and ozone in the atmosphere? If so, what is that relationship? If not, why do you say there isn't?

As the concentration of ClO increases, the concentration of ozone decreases.

IV. Arctic Ozone Levels

(http://jwocky.gsfc.nasa.gov/TOMSmarch79_94.gif)

1. In your opinion, is there or is there not a growing ozone "hole" in the Northern Hemisphere? Why or why not?

In March 1991, the concentration of ozone is much greater at the north pole than over North America. There is a steady loss of red and green colors in the photos towards the north pole as years progress. In 1993, the concentration of ozone over the north pole is almost the same as the concentrations over North America. These observations indicate that there is a growing ozone "hole" over the Arctic region, though not as pronounced as the one in Antarctica.

Kinetics Grid Questions

Name: ____________________

Date: ____________________

Period: ____________________

ⓐ catalyst	ⓑ chemical "sink"	ⓒ concentration
ⓓ unstable	ⓔ stable	ⓕ surface area
ⓖ the nature of reactants	ⓗ the rate of a reaction	ⓘ temperature

Use the letters that are circled to fill in the blanks in the sentences. Sometimes there is more than one correct answer. Put all the correct answers in the blank if you think there is more than one correct answer.

1. How fast a reaction takes place is the same as __________.
2. Reactions that include __________ molecules have faster reaction rates.
3. Reactions that include __________ molecules have slower reaction rates.
4. __________ are factors that influence the rate of a reaction.
5. An increase in __________ will cause an increase in energy so that more collisions can lead to reactions.
6. An increase in __________ of the reactants will cause an increase in the number of reactant molecules so more collisions will occur.
7. An increase in __________ of the reactants will cause more direct contact (collisions) so the reaction rate will increase.

8. CFC's are ________ molecules; they don't react until they reach the stratosphere.

9. Statement #8 is an example of how ___________ affects reaction rates.

10. A __________ can increase the speed of a reaction, but does not become depleted.

11. Ozone is a(n) ________ molecule, and is reactive.

12. A ______________ is a highly stable molecule that removes an an unstable molecule or atom from the atmosphere.

13. Spring sunrise in Antarctica increases the rate of ozone depletion by increasing the ______________.

14. Molecules in the solid phase have a greater ___________ and a faster _____________ than molecules in a gas phase.

15. In the process of ozone depletion, the role of chlorine is to be a _________.

16. Tiny frozen particles over Antarctica increase the _____________ of ozone depletion.

Kinetics Grid

TEACHER BACKGROUND

ⓐ catalyst	ⓑ chemical "sink"	ⓒ concentration
ⓓ unstable	ⓔ stable	ⓕ surface area
ⓖ the nature of reactants	ⓗ the rate of a reaction	ⓘ temperature

Use the letters that are circled to fill in the blanks in the sentences. Sometimes there is more than one correct answer. Put all the correct answers in the blank if you think there is more than one correct answer.

1. How fast a reaction takes place is the same as the ____h____.

2. Reactions that include __d (or a)__ molecules have faster reaction rates.

3. Reactions that include __e (or b)__ molecules have slower reaction rates.

4. __a,b,c,f,g,i__ are factors that influence the rate of a reaction.

5. An increase in ____i____ will cause an increase in energy so that more collisions can lead to reactions.

6. An increase in ____c____ of the reactants will cause an increase in the number of reactant molecules so more collisions will occur.

7. An increase in ____f____ of the reactants will cause more direct contact (collisions) so the reaction rate will increase.

8. CFC's are ____e____ molecules; they don't react until they reach the stratosphere.

9. Statement #8 is an example of how ____g____ affects reaction rates.

10. A ___a____ can increase the speed of a reaction, but does not become depleted itself.

11. Ozone is a(n) ___d____ molecule, and is reactive.

12. A _____b_____ is a highly stable molecule that removes an unstable molecule or atom from the atmosphere.

13. Spring sunrise in Antarctica increases the rate of ozone depletion by increasing the ___i_______.

14. Molecules in the solid phase have a greater ___c____ and a faster _____h____ than molecules in a gas phase.

15. In the process of ozone depletion, the role of chlorine is to be a ___a____.

16. Tiny frozen particles over Antarctica increase the ____h______ of ozone depletion.